5 Screening of Remedial Technologies

Under MTCA, the development of a cleanup plan requires that technologies capable of meeting cleanup objectives are screened, and then assembled into remedial alternatives. These are then evaluated, compared and preferred alternative(s) are identified. Section 3 presented the site cleanup goals and remedial action objectives for the Whatcom Waterway site. This section reviews available cleanup technologies, and selects a range of technologies to be retained for development of cleanup alternatives as described in Section 6.

The screening of remedial technologies provided in this section is performed using the process defined in the SMS guidance (Ecology, 1991). First, the range of potential technologies available for remediation of site contaminants is reviewed. Then, available technologies are screened for overall effectiveness, implementability and relative cost to identify a short-list of potentially applicable technologies for further evaluation.

The technologies that can be used to address contaminated sediments, as discussed in the SMS guidance (Ecology, 1991), and the ARCS (USEPA, 1994) are described in the following sections:

- Institutional Controls (Section 5.1)
- Natural recovery (Section 5.2)
- Containment (Section 5.3)
- Sediment Removal (Section 5.4)
- Sediment Disposal and/or Reuse (Section 5.5)
- *Ex situ* Treatment (Section 5.6)
- *In situ* Treatment (Section 5.7)

MTCA regulations place a preference on the use of permanent cleanup methods such as removal, disposal or treatment relative to those that manage contaminants in place using institutional controls, natural recovery and/or containment. This preference is reflected in regulatory evaluation criteria which are described and applied in Sections 6 and 7.

Sections 5.1 through 5.7 describe each of the technologies evaluated during technology screening, including information on the technology effectiveness, implementability and cost. Retained technologies to be carried forward in development of remedial alternatives are summarized in Section 5.8.

5.1 Institutional Controls

Institutional controls are mechanisms for ensuring the long-term performance of cleanup actions. They are applicable to most remedies where contaminants are not completely removed from the site. Institutional controls involve administrative/legal tools to document the presence of contaminated materials, regulate the anthropogenic disturbance/management of these materials, and provide for long-term care of remedial actions including long-term monitoring. Institutional controls have been successfully applied during remediation projects at Puget Sound sites including the Foss Waterway in Tacoma, the Lockheed and Todd Shipyards Operable Units at Harbor Island.

For sediment remediation projects, permitting review procedures constitute institutional controls. For any aquatic construction project (e.g., dredging in a berth area) environmental reviews are conducted by permitting agencies including the Corps of Engineers, the Department of Ecology, and other resource agencies. These reviews include a review of area files relating to sediment conditions, and requirements to address materials management and water quality.

Additional institutional controls may be implemented as appropriate, depending on the preferred remedial alternative ultimately selected by Ecology. Such additional controls could include restrictive covenants for platted tidelands, use authorizations for state-owned aquatic lands, and/or documenting the site remedial action in County property records, Corps and regulatory agency permit records and/or records maintained by the State of Washington for state-owned aquatic lands.

Institutional controls can be highly effective, implementable, and cost-effective provided that the remedial action for which the institutional controls are implemented is consistent with area land and navigation uses. In cases where the proposed remedial action is in conflict with land use and navigation uses, conflicts can result that jeopardize the effectiveness of institutional controls or that require mitigation.

Institutional Controls have been carried forward in the Feasibility Study for alternatives development.

5.2 Natural Recovery

Natural recovery of contaminated sediment may occur over time and may lower the surface concentrations of sediment contaminants. Natural recovery of sediments in the Whatcom Waterway area has been well documented by the historical record of declining surface concentrations of mercury over the past 25 years. Section 6.2 of the RI Report contains a discussion of site natural recovery data. Natural recovery includes three processes that contribute to the cleanup of surface sediments. These processes include the following:

1) Physical processes, such as sedimentation/deposition and mixing

2) Biological degradation processes that cause reductions in the mass, volume, and/or toxicity of contaminants through biodegradation or biotransformation

3) Chemical processes, including oxidation/reduction and sorption.

As discussed in the Remedial Investigation report, natural recovery through the physical process of sediment deposition has been highly effective at restoring sediment quality in the bioactive zone throughout much of the Whatcom Waterway site.

Biological processes include bacterial or fungal degradation or transformation of organic chemicals into less toxic forms. These processes may be effective for volatile and semivolatile organic compounds in well-aerated sediments. Metals concentrations would not be expected to decrease through biological processes, although the natural production of sulfides may result in the formation of metal-sulfide complexes, thereby limiting the bioavailability of certain metals (EPA 2000e). Biological processes may produce long-term reductions of organic constituents, such as phenolic compounds.

Chemical processes include the preferential sorption of organic compounds to naturally occurring carbon and humic sources within the sediments, as well as changes in redox potential and chemical precipitation reactions that chemically bind contaminants to sediments and reduce their toxicity. For example, many metal compounds form stable precipitates with hydrogen sulfides in sediments.

All of these processes (physical, biological, chemical) can occur together and contribute to overall recovery of sediment systems.

5.2.1 Monitored Natural Recovery

Monitored natural recovery (MNR) relies on natural recovery processes coupled with monitoring to ensure that recovery achieves stated cleanup levels and remedial action objectives. Natural recovery is defined as the effects of natural processes that permanently reduce risks from contaminants in surface sediments (Apitz et al. 2002) and that effectively reduce or isolate contaminant toxicity, mobility, or volume. Monitoring of these processes is conducted to determine their effectiveness within a prescribed time frame.

MNR is a risk management alternative that relies upon natural environmental processes to permanently reduce exposure and risks associated with contaminated sediments (Davis et al. 2004) MNR can be implemented as a sole alternative, but is more frequently combined with other active measures and institutional controls. MNR differs from No Action in that, by definition, it must include source control, appropriate assessments including modeling, and long-term monitoring to verify the remedy effectiveness (Palermo 2002; Apitz et al. 2002).

The potential for natural recovery of sediment is determined through multiple lines of evidence related to the biological, physical, and chemical processes described above. A thorough assessment of natural recovery was performed as part of the 2000 RI/FS (Hart Crowser and Anchor Environmental, 2000). This assessment showed that natural recovery was occurring at the site, which has since been verified during additional sampling events in 2002, as evidenced by the decreasing surface sediment concentrations.

Where MNR has been applied successfully, the demonstration of sediment deposition (burial) and contaminant attenuation (reduction) processes have been major determinants of MNR. MNR has been applied as a portion of the remedy in conjunction with active remedies at many Puget Sound sites, including the Puget Sound Naval Shipyard site in Bremerton, Washington (Palermo 2002) and portions of the Commencement Bay site in Tacoma, WA (EPA 1989). Performance at these sites have shown the technology to be effective and implementable when applied in suitable areas. Costs of the technology are primarily associated with implementation of institutional controls and long-term monitoring.

5.2.2 Enhanced Natural Recovery

ENR involves the placement of a thin layer of clean material over areas with relatively low contaminant concentrations to speed up, or enhance, the natural recovery processes already demonstrated to be occurring at a site. Under ENR, thin layers of clean sand or sediments are placed over areas where natural recovery processes are occurring. The new material reduces the restoration time-frame required for natural recovery to be effective and comply with site cleanup levels (OSWER 2004). ENR has been used in Puget Sound both as a sole remedy and in conjunction with removal actions to aid in the management of post-dredging contaminant residuals. ENR frequently also includes a long-term monitoring component as with MNR. ENR has been selected as a remedy component at Superfund sites in Commencement Bay (Tacoma, Washington) and Eagle Harbor (Bainbridge Island, Washington) (Thompson et al. 2003).

Enhanced natural recovery has been highly effective in managing residual sediment left following dredging. In this case, the dredging operation is designed to remove the majority of the contaminated sediment. However, all dredging technologies leave some residual materials on the dredged surface, at times resulting in short-term non-compliance with the site cleanup level. ENR can be used to address this residual provided that the quantity of the residuals is minimized through the use of best practices during dredging.

For purposes of the Feasibility Study, only MNR has been carried forward for alternatives development. ENR is retained in the context of post-dredge residuals management, but not as a discrete remedial technology.

5.3 Containment

Containment involves either confining the contaminated sediments in place or confining dredged materials within a disposal facility after removal.

Containment technologies have been used extensively in remediation of contaminated sediments elsewhere in Puget Sound.

5.3.1 Sediment Capping

Capping is a well-developed and documented cleanup alternative in the Pacific Northwest and nationally. One of the first, and best-documented, examples of capping occurred in 1984, when contaminated fine-grained sediment dredged from the LDW navigation channel between Kellogg Island and the Duwamish Diagonal CSO and storm drain was disposed of in a borrow pit in the West Waterway; that material was capped with clean sand dredged from the LDW's upper turning basin (Sumeri 1984, 1989; USACE 1994). As recently as 1995, monitoring demonstrated that the capped contaminated sediment remained effectively isolated (USACE et al. 1999). Numerous other caps have been successfully placed in Puget Sound, including the capping of the Log Pond during the Interim Remedial Action at the Whatcom Waterway site.

Capping isolates contaminants from the overlying water column and prevents direct contact with aquatic biota. Cap placement as a remedial alternative assumes source control to protect against cap recontamination. If the potential for scour from river currents or propeller wash exists, the cap must be designed in a way that protects it from these disruptive forces.

Caps may be used in different ways as part of a remedial action:

- ***In Situ* Capping** is defined as the placement of an engineered subaqueous cover, or cap, of clean isolating material over an *in situ* deposit of contaminated sediment (EPA 1994, 2002; NRC 1997, 2001; Palermo et al. 1998a, 1998b). Such engineered caps are also called isolation caps. *In situ* caps are generally constructed using granular material, such as clean sediment, sand, or gravel. Composite caps can include different types and multiple layers of granular material, along with geotextile or geomembrane liners. Reactive caps can include the addition of contaminant-sorbing or blocking materials. *In situ* capping may be considered as a sole remedial alternative or may be used in combination with other remedial alternatives (e.g., removal and MNR).

- ***In Situ* Capping After Partial Removal** is an option involving placement of an *in situ* cap over contaminated sediments that remain in place following a partial dredging action that removes contaminated sediment to some specified depth. This can be suitable in circumstances where capping alone is not feasible because of habitat, navigation or land use requirements that necessitate a minimum water depth. *In situ* capping with partial dredging can also be used when it is desirable to leave deeper contaminated sediment capped in place so as to preserve bank or shoreline stability, or where dredging of the materials creates excessive disruption or water quality impacts. When *in situ* capping is used with partial dredging, the cap is designed as an engineered isolation cap, because a portion of the contaminated sediment deposit is not dredged.

Cap Construction Methods

Various equipment types and placement methods have been used for capping projects, including placement using hopper barges at larger, open-water sites and both hydraulic and mechanical systems for placement at nearshore or shallow-water sites.

An important consideration in the selection of placement methods is the need for controlled, accurate placement of capping materials. Slow, uniform application that allows the capping material to accumulate in layers is often necessary to avoid displacement of or mixing with soft underlying contaminated sediments. Slow application also minimizes the resuspension of contaminated material into the water column (Cunningham et al. 2001).

Granular cap material can be handled and placed in a number of ways. Mechanically dredged materials that have been dewatered and soils that have been excavated from an upland site or quarry have relatively little free water. These materials can be handled mechanically in a dry state until released into the water over the contaminated site. Mechanical methods (such as clamshells or release from a barge) rely on gravitational settling of cap materials in the water column and are highly effective at shallow and intermediate depths such as those within the Whatcom Waterway site. Granular cap materials can also be entrained in a water slurry and carried wet to the contaminated site, where they are discharged into the water column at the surface or at depth. These hydraulic methods offer the potential for a more precise placement, although the energy required for slurry transport must be controlled at the point of release to prevent resuspension of contaminated sediment. Armor layer materials (stone materials placed to resist cap erosion) can be placed from barges or from the shoreline using conventional equipment, such as clamshells.

Capping Decision Factors

The principal design considerations for capping as a remedial alternative for contaminated sediments are that the cap must remain physically stable, and that the contaminants are effectively isolated. The National Research Council (NRC 1997) provided additional decision factors that encourage use of capping as a cleanup technology include the following

- Contaminant sources have been sufficiently abated to prevent re-contamination of the cap

- Contaminants are of moderate to low toxicity and mobility

- MNR is too slow to meet remedial action objectives (RAOs) in a reasonable time frame
- Cost and/or environmental effects of removal are very high
- Suitable types and quantities of cap materials are available
- Hydrologic conditions will not compromise the cap if designed appropriately
- Weight of the cap can be supported by the physical properties of the underlying sediments
- The application of the cap is compatible with current and/or future navigation and land uses in the cap area
- Site conditions do not necessitate removal of contaminated sediment.

A well-designed, properly constructed and placed cap over a contaminated surface, along with effective long-term monitoring and maintenance, can prevent direct contact by aquatic biota by providing long-term isolation of contaminated sediments. The cap can also prevent contaminant flux into the surface water. Incorporation of habitat elements into the cap design can provide an improvement or restoration of the biological community.

One advantage of capping is that the potential for contaminant resuspension and the risks associated with dispersion of contaminated materials during construction are relatively low. With capping, the sediments are contained in-place, and do not require additional treatment and/or offsite disposal. Most capping projects use conventional and locally-available materials, equipment, and expertise. For this reason, in certain cases the *in situ* capping option may be implemented more quickly and may have much lower short-term risks than options involving removal and disposal or treatment. Depending on the location of the cap, the type of construction, and the availability of materials, a cap may be readily repaired, or enhanced if necessary.

Capping designs must anticipate and protect against potential disturbance events such as storm events and propeller wash. These events are factored into the remedy selection, design, institutional controls, and monitoring to ensure long-term integrity of the cap. To provide erosion protection, it may be necessary to use cap materials that are different from native bottom materials. This can benefit or improve the habitat quality in the cap areas, and the project design and permitting must consider these potential habitat impacts and/or benefits.

Palermo et al. (2002) and the EPA (OSWER 2004) provided additional considerations to ensure effective and implementable design, placement, and long-term maintenance of a cap over contaminated sediments that include:

- Evaluation of navigation and land use priorities in the cap area
- The impacts and/or benefits to habitat by cap placement should be considered, including changes to depth and substrate type
- The composition and thickness of the cap components comprise the cap design. A detailed design effort for any selected capping remedy should address all pertinent design considerations
- The cap should be designed to provide physical and chemical isolation of the contaminated sediments from benthic organisms
- The cap should be physically stable from scour by hydraulic conditions including currents, flood flow, propeller wash, etc.
- The cap should provide isolation of the contaminated sediments from flux or resuspension into the overlying surface waters
- The cap design should consider operational factors such as the potential for cap and sediment mixing during cap placement, resuspension during placement, and variability in the placed cap thickness
- The cap design should incorporate an appropriate factor of safety to account for uncertainty in site conditions, sediment properties, and migration processes.

Capping costs vary with the design of the cap. Costs of capping are associated with cap design, construction, institutional controls and long-term monitoring. Capping has been carried forward in the Feasibility Study for alternatives development.

5.3.2 Confined Nearshore Disposal

A Confined Nearshore Disposal (CND) facility or a "nearshore fill" is an engineered containment structure that provides for dewatering and permanent storage of dredged sediments. CNDs feature both solids separation and landfill characteristics (EPA 1994a). Containment of contaminated sediments in CNDs is generally viewed as a cost-effective remedial option at Superfund sites (EPA 1996b). Interest in CNDs for disposal of contaminated dredged sediment has led both the USACE and the EPA to develop detailed guidance documents for their construction and management (USACE 1987, 2000; EPA 1994, 1996; Averett et al 1988; Brannon et al 1990).

CND facilities involve creation of a sediment containment area that has a final filled surface located above tidal elevations. CNDs are commonly known as nearshore fills, because they involve filling of aquatic areas and conversion of those areas to upland use.

CNDs have a good performance record in Washington State. These include the Milwaukee Waterway, Eagle Harbor East Operable Unit, and the recent Blair Waterway Slip 1 Nearshore CND. However, their use has been declining due to habitat considerations, and the availability of other options such as Confined Aquatic Disposal that accomplish sediment containment without eliminating aquatic habitat.

Potential CND facilities were evaluated in the Final Disposal Siting Documentation Report (Siting Documentation Report; BBWG, 1998) during the work of the Bellingham Bay Pilot. The Pilot analysis concluded that use of a CND site would be implementable and effective. The area offshore of the Cornwall Avenue Landfill and the GP Log Pond were evaluated in this report as potential locations for a CND.

Use of the Aerated Stabilization Basin (ASB) as a CND was not included in the original Siting Documentation Report because it was anticipated that the ASB would indefinitely continue use as a wastewater treatment basin. Since that time, GP has substantially reduced its operations in Bellingham, including closure of its pulp mill, chemical plant and chlor-alkali plant. In 2001, GP identified a portion of the ASB as being available for siting of a CND facility for containment of dredged sediments from the Whatcom Waterway. The use of the ASB for construction of a CND facility was identified as an element of a preferred remedial alternative in a Supplemental Feasibility Study (Anchor, 2002).

If the ASB was used for construction of a CND, a berm would be constructed across the CND, segregating a portion of the CND which would continue to be used for wastewater treatment from the portion which would be used for disposal of sediments. Dredged sediments would be placed inside the disposal section of the ASB, along with any ASB sludges from the "outer" portion of the facility. Cleaner sediments and new structural fill soil would be placed above the sediments to form a cap and working surface above the sediments. The 2002 Supplemental Feasibility Study identified a proposed fill area that would occupy approximately 20 acres. The ASB CND option received significant comment during public review of the 2002 Supplemental Feasibility Study, including opposition from the Port and City due to land use considerations.

The ASB nearshore fill option has been carried forward in the Feasibility Study for evaluation as part of the current Feasibility Study. As described in Section 4.7.1, the ASB sludges are soft, wet and have very high TOC contents. If managed as part of a nearshore fill, these sludges would be subject to primary and secondary consolidation, and would likely produce methane during anaerobic decomposition.

5.3.3 Confined Aquatic Disposal

Confined Aquatic Disposal (CAD) facilities are similar to CNDs. Like CND facilities, CAD facilities are constructed in in-water areas and are used to contain sediment dredged from other areas. However, the surface of the CAD facility is constructed so that its final elevation retains overlying aquatic uses. In some cases the CAD surface is designed with a surface that provides enhanced habitat conditions.

CAD sites have been successfully applied in the Duwamish West Waterway for dredged sediments in 1984. In addition, a CAD was recently used as for the disposal of contaminated sediments dredged from Pier D at the Puget Sound Naval Shipyards in Bremerton, Washington.

Potential Confined Aquatic Disposal options were evaluated in the Siting Documentation Report of the Bellingham Bay Demonstration Pilot (BBWG, 1998). This report determined that CADs for contaminated sediments from Bellingham Bay would be implementable and effective. Three potential CAD sites were identified, an area offshore of the Cornwall Avenue landfill, the area within the Log Pond, and an area in sediment Unit 5 offshore of the ASB facility.

The evaluation of disposal siting alternatives conducted during the Bellingham Bay Demonstration Pilot developed an option for a CAD facility located adjacent to the Cornwall Avenue Landfill. Properly constructed, the CAD option provided a potential method of enhancing the quantity of premium nearshore habitat in the facility area. If this site were selected, a containment berm would be constructed near the subtidal portions of the Cornwall Avenue Landfill. Dredged sediments would be placed behind the berm, and the site would be capped with approximately three feet of clean fill. The finished grade of the area inside the berm could range from approximately -10 to -2 feet MLLW elevation, which would be suitable for use as subtidal habitat. The CAD surface would be protected from erosion using a hard leading edge that would reduce the energy of incoming waves, and allow for potential colonization of the cap surface by eel grass.

A range of CAD facility sizes for the Cornwall area was evaluated, including containment volumes ranging from approximately 260,000 to 1,000,000 cubic yards of sediment. The final footprint, costs and habitat benefits of a facility would vary with its size. The smaller size facilities were generally less cost-effective than those with larger (i.e., at least 500,000 cubic yard) capacities. The use of a Cornwall CAD site for containment of sediments dredged from the Whatcom Waterway was identified as a preferred alternative during the 2000 EIS process.

The Cornwall CAD option is retained for further consideration as part of the current Feasibility Study.

5.4 Sediment Removal

Contaminated sediments can be removed, typically through dredging or excavation. After removal, the sediments must be managed, a process that can include dewatering, treatment and/or disposal. In some cases, the physical and chemical properties of sediments allow them to be beneficially reused.

Dredging is commonly used for both maintenance of navigation channels and removals of contaminated sediments. Dredging is typically either mechanical dredging, which removes sediments by digging them using a bucket, or hydraulic dredging, which mechanical means to loosen sediments and then uses water suction to remove and transport the loosened sediments. Excavation of sediments is a variant of mechanical dredging, and is typically used in certain situations where it may be more effective than other means of dredging.

Dredging is such a commonly used technology, and has been applied to multiple sediment remediation projects in Puget Sound, such as the Hylebos Waterway in Tacoma and the Duwamish Waterway in Seattle. After removal of sediments, the sediments must be appropriately managed using containment, beneficial reuse, disposal, or treatment.

Removal refers to excavation or dredging of sediments. The discussion of removal process options herein integrates site knowledge, practical dredging experience, dredging sediment case studies, and demonstrated successful application under similar conditions. The following documents include practical information relating to sediment remediation projects in the United States:

- Assessment and Remediation of Contaminated Sediments (ARCS) Program, Remediation Guidance Document (EPA 1994b)

- Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes (Averett et al. 1990)

- Removal of Contaminated Sediments: Equipment and Recent Field Studies (Herbich 1997)

- Innovations in Dredging Technology: Equipment, Operations, and Management, USACE DOER Program (McLellan and Hopman 2000)

- Dredging, Remediation, and Containment of Contaminated Sediments (Demars et al. 1995).

Dredging has been used for remediation at many Puget Sound projects of a similar scale to the Whatcom Waterway Site. Some recent projects include: the 2004 Duwamish/Diagonal Way Combined Sewer Overflow (CSO) and Storm Drain Early Action Removal Project, the 1999 Norfolk CSO Early Action Removal Project, both located in the Duwamish Waterway, and the 2004 Harbor Island East Waterway Sediment Phase 1 Cleanup Project, located at the mouth of the Duwamish. The latter project was a relatively large-scale removal project, dredging from a 20-acre area, with disposal of 200,000 cubic yards (cy) of sediment to an upland landfill and another 59,000 cy to the Elliott Bay Disposal Area. Two additional sediment remediation projects located within the Harbor Island Superfund Site involve dredging contaminated sediments using a closed bucket, with landfill disposal of wet sediments. These are the Lockheed Shipyard Sediment Operable Unit (dredging 130,000 cy with disposal at an upland landfill and capping of deeper sediments) and the Todd Shipyard Operable Unit (dredging 200,000 cy with disposal at an upland landfill and capping of under-pier areas). Finally, the cleanup of the Hylebos Waterway within the Commencement Bay Superfund site includes dredging combined with multiple forms of sediment management including upland disposal and confined nearshore disposal.

5.4.1 Overview of Removal Options

For the purposes of this FS, dredging is defined as the removal of sediment in the presence of overlying water (subtidal and intertidal) utilizing mechanical or hydraulic removal techniques and operating from a barge or other floating device. Excavation is defined as the dry or shallow-water removal of sediment using typical earth moving equipment such as excavators and backhoes operating from exposed land or wharves. Depending on the location of the sediments being removed, there may be some overlap in the equipment used for dredging and excavation. For example, a barge mounted excavator could reach over into a shallow area to remove sediments, or a shore-based crane with a long boom could reach out into deeper water and dredge these sediments.

There are two major types of dredges, mechanical and hydraulic. Mechanical dredges function by digging into the sediments with a bucket, similar to a land-based process. Hydraulic dredges function by loosening sediments with a mechanical device, and then "vacuuming" the sediments along with large quantities of entrained water, and transporting the resulting dredge slurry in a pipeline to an area where the solids and liquids can be separated for subsequent management.

Mechanical dredges remove material at near *in situ* conditions, with lower levels of water entrainment. The dredged material is taken up through the water column to a barge for transport. Mechanical dredges may be used for a wide range of material types (loose to hard consolidated and compacted material). A subset of mechanical dredges, excavators, are often used to preremove large debris prior to dredging, or are used in difficult to access, shallow, and backwater areas.

Hydraulic dredges remove material as a low-density slurry; with water entrainment ratios commonly exceeding 10 to 1 (i.e., 10 cubic yards of water are entrained during the removal of 1 cubic yard of in-place sediment). The slurried dredged material is transported through a pipeline to a selected land-based dewatering facility. Hydraulic dredges are typically used for relatively loose, unconsolidated material with little debris, and where the slurry can be separated and the generated water can be managed in a cost-effective and environmentally sound manner.

Dredging in the United States is typically conducted by one of these basic methods (i.e., mechanical, hydraulic or excavation) depending upon accessibility, the volume of sediment to be removed, the disposal option selected, and site conditions. Dredging operations use not only the dredging equipment, but also significant other equipment for work over the water and management of the removed sediment. A typical dredge system includes:

- Point of dredging components include the cutterhead, auger screw, dustpan, and matchbox of hydraulic dredging systems, as well as various mechanical means, such as clamshell or backhoe excavator buckets for mechanical dredging systems.

- Support components include the support barge or pontoon, jack-up platforms, amphibious systems, monitoring and confirmation sampling equipment, and positioning systems.

- Discharge components include pumps, pipelines, dewatering and water treatment facilities, barges, and transport.

Selection of dredging equipment and methods used for a site depend on several factors, including: physical characteristics of the sediments to be dredged, the quantity and dredge depth of material, distance to the disposal area, the physical environment of the dredge and disposal areas (especially tidal range), contaminant concentrations in the sediment, method of disposal, production rates required for removal, equipment availability, amount and type of debris present, ability to manage produced waters, and cost (EPA 2004).

5.4.2 Mechanical Dredging

A mechanical dredge typically consists of a suspended or manipulated bucket that bites the sediment and raises it to the surface via a cable, boom, or ladder. The sediment is deposited on a haul barge or other vessel for transport to disposal sites. Mechanical dredges have been the principal tool used for environmental dredging in Puget Sound.

Under suitable conditions, mechanical dredges are capable of removing sediment at near *in situ* densities, with almost no additional water entrainment in the dredged mass and little free water in the filled bucket. A low water content is important if dewatering is required for ultimate sediment treatment or upland disposal, as well as to minimize water quality impacts at the point of dredging.

Clamshell buckets (open, closed, hydraulic-actuated), backhoe buckets, dragline buckets, dipper (scoop) buckets, and bucket ladder are all examples of mechanical dredges. Dragline, dipper (scoop), and bucket ladder dredges are open-mouthed conveyances and are generally considered unsuitable where sediment resuspension must be minimized to limit the spread of sediment contaminants (EPA 1994a).

- **Clamshell Dredges:** The clamshell bucket dredge, or grab dredge, is widely used in the United States and throughout the world. It typically consists of a barge-mounted floating crane maneuvering a cable-suspended dredging bucket, with or without teeth. A heavy bucket with teeth can dig harder sediments than can a lighter bucket without teeth. The crane barge is held in place for stable accurate digging by deploying vertical spuds into the sediment. The operator lowers the clamshell bucket to the bottom, allowing it to sink into the sediment on contact. The bucket is closed, then lifted through the water column to the surface, swung to the side, and emptied into a waiting haul barge. When loaded, the haul barge is moved to shore where a second clamshell unloads the barge for rehandling and/or transport to treatment or disposal facilities. Clamshell dredges work best in water depths less than 100 feet to maintain production efficiency. Using advanced positioning equipment (e.g., differential global positioning systems [DGPS]), dredging accuracy is on the order of 1 foot horizontally and 0.5 foot vertically. Clamshell buckets are designated by their digging capacity when full and range in size from less than 1 cy to more than 50 cy. A conventional clamshell bucket may not be appropriate for removal of contaminated sediments in some areas. Conventional buckets have a rounded cut that leaves a somewhat "cratered" sediment surface on the bottom. This irregular bottom surface increases the need to overdredge to achieve a minimum depth of cut, and multiple passes to achieve adequate removal. Furthermore, the conventional open clamshell bucket is prone to sediment losses during retrieval. Recent innovations in bucket design have reduced sediment resuspension potential by enclosing the bucket top. Also, buckets can be fitted with tongue-in-groove rubber seals to limit sediment losses through the bottom and sides. Finally, local Puget Sound dredging contractors have recognized the need to minimize resuspension while using a clamshell bucket, and have developed modifications to both their equipment and to the operations to reduce sediment loss.

- **Environmental Dredge:** A recent development in the environmental dredging field has been the advent of specialty level-cut buckets. These buckets offer the advantages of a large footprint, a level cut, the capability to remove even layers of sediment, and, under careful operating conditions, reduced resuspension losses to the water column. A level-cut bucket reduces the occurrence of ridges and winnows that are typically associated with conventional clamshell buckets. The Cable Arm™ bucket is one such environmental bucket that has been successfully demonstrated for contaminated sediment removal. Several of the Puget Sound area dredging companies own and use Cable Arm closed buckets (Wang et al. 2003). Local projects where the closed buckets have been used include Pier D at the Puget Sound Naval Shipyard in Bremerton, and at the East Waterway of the Duwamish River. Environmental buckets have been shown to be effective in loose sands and in low-solids soft-sediments. The light construction of the bucket makes it unsuitable for dredging dense or native material (Wang et al. 2003).

- **Excavator Dredges:** This is a subset of mechanical dredges, which includes barge-mounted backhoes and/or excavators, both of which have limited reach capability (maximum depth typically less than 40 feet). Excavators can also be used for dry excavation after the overlying water is removed. Special closing buckets are available to reduce sediment losses and entrained water during excavation. A conventional excavator bucket is open at the top, which may contribute to sediment resuspension and loss during dredging, although careful operation can minimize losses. Various improved excavating buckets have been developed that essentially enclose the dredged materials within the bucket prior to lifting through the water column. A special enclosed digging bucket, the Horizontal Profiling Grab (HPG), was successfully used on the large excavator – the Bonacavor (C. F. Bean Corp.) for remediation of highly contaminated sediment at the Bayou Bonfouca Site (Slidell, Louisiana) (NRC 1997), and was recently used for dredging contaminated sediments in the Hylebos Waterway in Tacoma. The bucket has a capacity of 4.5 cubic meters and can operate in water depths up to 13 meters. Dredged material removed by backhoe exhibits much the same characteristics as for clamshell dredging, including near *in situ* densities and limited free water.

5.4.3 Hydraulic Dredging

Hydraulic dredges remove and transport large quantities of dredged materials as a pumped sediment-water slurry. The sediment is dislodged by mechanical agitation, cutterheads, augers, or by high-pressure water or air jets. The loosened slurry is then vacuumed into the intake pipe by the dredge pump and transported over long distances through the dredge discharge pipeline. A key difference between hydraulic dredging and mechanical dredging is the generation of a high volume of contaminated water during hydraulic dredging. That water must treated before discharge to ensure that the quality of the surface-water body is not compromised by the dredging activity, and to protect against sediment recontamination.

Common hydraulic dredges include three main categories: the conventional pipeline dredge (round cutterhead, horizontal auger cutterhead, open suction, bucket wheel, dust pan, etc.), the self-propelled hopper dredge, and sidecasting dredge (EPA 1994; Herbich 2000). A sidecasting dredge takes dredged material excavated from the sediments and “side casts” the material from the dredge to adjacent shoreline areas. It can be used to replenish beaches, but is not used for environmental dredging.

Hydraulic dredges have four key components: the dredgehead, which is in contact with and digs the sediment, a support structure (wire or ladder) for the head assembly, the hydraulic pump to provide suction, and the pipeline that carries sediment slurry away from dredging operations. Specialty hydraulic dredges are available that limit resuspension losses at the dredgehead and increase the solids content of the dredged slurry. These include the auger-, cleanup-, airlift-, and refresher-type dredges. Hydraulic dredges are rated by discharge pipe diameter, ranging from smaller portable machines in the 6- to 16-inch category, to large 24- to 30-inch dredges. Two commonly used hydraulic dredges are the pipeline and cutterhead types.

- **Suction Dredge:** Suction dredges are open-ended hydraulic pipes that are limited to dredging soft, free flowing, and unconsolidated material. Because suction dredges are not equipped with any kind of cutting devices, they produce very little resuspension of solids during dredging. However, the presence of trash, logs, or other debris in the dredged material will clog the suction and greatly reduce the effectiveness of the dredge (Averett et al. 1990). Suction dredges have been used with limited success in the Northwest for difficult access areas such as the underpier areas of the Sitcum Waterway Superfund Site (Tacoma, Washington) and at the Port of Portland T4 Pencil Pitch Removal Project (Portland, Oregon), often with diver assistance.

- **Cutterhead Dredge:** The hydraulic pipeline cutterhead suction dredge is the most commonly used method in the United States, with approximately 300 operating nationwide. The cutterhead is considered efficient and versatile (Averett et al. 1990). It is similar to the open suction dredge, but is equipped with a rotating cutter surrounding the intake of the suction pipe. The combination of mechanical cutting action and hydraulic suction allows the dredge to work effectively in a wide range of sediment environments. Resuspension of sediments during cutterhead excavation is strongly dependent on operational parameters such as thickness of cut, rate of swing, and cutter rotation rate. Proper balance of operational parameters can result in suspended sediment concentrations as low as 10 milligrams per liter (mg/L) in the vicinity of the cutterhead. More commonly, cutterheads produce suspended solids in the 50 to 150 mg/L range (10 to 20 percent solids by weight) (EPA 1994b). Slurry uniformity and density are controlled by the cutterhead and suction intake design and operation. By pivoting the spuds used to anchor the barge in place, the dredge “steps” or “sets” forward for the next swing. Cutterhead dredges have been used at numerous sites in the Northwest and nationally, including the Sitcum Waterway Superfund Site (Washington), Lower Fox River (Wisconsin), and New Bedford Harbor (Massachusetts). Dredge residuals with cutterheads can be as much as a foot in thickness, and are frequently greater than ½ foot.

- **Auger Dredge:** The horizontal auger dredge is a relatively small portable hydraulic dredge designed for projects where a small (50 to 120 cy/hr) discharge rate is desired. In contrast to a cutterhead, the auger dredge is equipped with horizontal cutter knives and a spiral auger that cuts the material and moves it laterally toward the center of the auger, where it is picked up by the suction. There are more than 500 horizontal auger dredges in operation. A specialized horizontal auger dredge has been used at the Manistique Harbor Superfund site (Manistique, Michigan), the Marathon Battery Superfund site (Massena, New York), and the Lake Jarnsjon sediment remediation site (Sweden)

- **Specialty Dredges:** A number of specialty hydraulic dredges have been used at cleanup sites, including but not limited to the following:

  - The Toyo™ pump is a proprietary electrically driven compact submerged pump assembly that is maneuvered into position using a derrick barge. This pump is capable of high solids production in uncohesive sediment and can be equipped with a rotating cutter or jet ring to loosen sediment. This is a lower head pump that typically discharges through 6- to 12-inch-diameter pipes and may require a booster pump for long pipeline distances. Typically, slurry discharges are at a density of approximately one-third the *in situ* density. This specialty dredge was used at the mouth of the Hylebos Waterway (Tacoma, Washington, Area 5106) to remove 32,000 cy of contaminated sediment and pumped into the Blair Slip 1 CND between October 2002 and March 2003.

- The Pneuma™ pump is a proprietary pump developed in Italy that uses a compressed air and vacuum system to transport sediments through a pipeline. It may be suspended from a crane or barge and generally operates like a cutterhead dredge. This specialty pump was used at the Collingwood Harbor Project (Ontario, Canada) demonstration dredging project (EPA 1994a).

- The Mudcat™, a proprietary dredge device, was fitted with a vibrating auger head assembly and positive displacement pump specifically designed to excavate difficult, very soft material from the Sydney Tar Ponds (Nova Scotia). The dredge unit was modified to float in very shallow water and was moved using onshore winching cables and pulleys. Mudcats™ are one of the most commonly employed dredging units in the country, and have been used at various environmental dredging projects including the Manistique Harbor, Michigan; SMU 56/57 in the Lower Fox River Wisconsin; and at the New Bedford PCB remedial action site.

5.4.4 Dewatered Excavations

Excavation refers to the removal of sediments in the absence of overlying water, as with upland excavation. This often involves the use of conventional excavating equipment, and is generally restricted to removal of contaminated sediment and debris in shallow-water environments, dry excavations (areas that are bermed, then dewatered for access by land-based equipment), or during low tides. Dewatering of an area for dry dredging involves hydraulic isolation/removal of surface water using: (1) earthen dams, (2) sheet piling, or (3) rerouting the water body. Although normally land based, excavators can be positioned on floating equipment (e.g., spud barge) for dredging in shallow environments.

Various track-mounted excavators have been developed to access shallow water marsh environments for dike construction, dredge material disposal operations, pipeline crossings, and have been adapted for intertidal dredging excavation. Conventional backhoes, crane buckets, dragline, and other excavator types have been adapted to self-propelled, tracked assemblies that can travel over low bearing capacity soils and shallow water environments. These systems work optimally in shallow water depths and emergent shoreline and tide flats. The production capacity of these excavators is generally limited, and depends upon the bearing capacity of the intertidal sediments and the size equipment needed for the dredge areas.

Two specialty excavators are the Amphibex and Aquarius amphibious excavators. These are barge-mounted backhoes, capable of turning 360 degrees. These systems work optimally in water depths of 8 to 13 feet, but can also work on emergent shoreline and tide flats, according to the manufacturers. The excavators are mounted atop barges that have been fitted with “legs” with cylindrical wheels that provide mobility. The Amphibex amphibious excavator can operate in either straight mechanical or hydraulic transport modes. The Aquarius amphibious excavator only operates in mechanical dredging and transport modes. The DRE Technologies – Dry Dredge integrates a closed bucket mechanical dredge with a positive displacement pump for high solids dredged material transport.

5.4.5 Dredging Decision Factors

Selection of the appropriate type of dredging technologies and their potential effectiveness is dependent upon more than one variable. Significant operating parameters and constraints considered in selecting and applying appropriate dredging equipment include sediment characteristics, site conditions, potential for sediment resuspension and transport, use of turbidity barriers, amount and type of debris, equipment availability, and removal accuracy. As noted previously, production rates, and water management will be key in determining the size of equipment selected. Work sequencing and management are also important factors to consider during the remedial design. Each of these variables is discussed below.

Sediment Characteristics

The physical characteristics of the sediments, including particle size, density, cohesion (strength), and plasticity (stickiness), interact and affect dredge performance and efficiency (USACE 1995). These factors should be considered when selecting dredge types, designing sediment dewatering facilities, calculating settling rates, and planning other aspects of remedial activities. Rocks and debris, if present, can interfere with dredging and delay the cleanup process, often creating more water quality resuspension problems. A combination of hydraulic and mechanical dredging has been used for some cleanup projects (Sitcum Waterway, Washington; Black River, Ohio; Marathon Battery, St. Lawrence River, New York; Lake Jarnsjon, Sweden) where debris interfered with large-scale dredging or access was difficult. Recent sediment dredging projects have incorporated pre-removal of boulders, wood timbers, and other debris using excavator equipment prior to initiating dredging (Grasse River, Massena, New York; GM Foundry/St. Lawrence River, New York). This requires a complete investigation (debris survey) to identify where debris is present.

Sediment Accessibility

Difficult to access areas (i.e., near pilings, floating docks/marinas, riprap slopes, and between pilings and bulkheads) may require use of specialized equipment to adequately remove contaminated sediments. Recent projects have included multiple removal techniques in the remedial design to address these difficulties. For example, the Port of Vancouver Copper Spill Project (Vancouver, Washington) used a hydraulic cutterhead dredge in open areas with 0.5 feet of overdredge and diver-assisted suction dredging in underpier areas. The Port of Portland T4 Pencil Pitch Site (Portland, Oregon) used a shrouded environmental clamshell bucket for open-water areas, while nearshore and underpier areas were excavated with an airlift pump. Yet another example includes the Wyckoff/West Eagle Harbor Superfund Site where environmental clamshell buckets were used for open-water areas and backhoes were used for underpier areas at low tide. Typically, the dredging of under-pier areas is inefficient and leaves significant dredge residuals. Capping is typically incorporated into the remedial design for these areas. The method carried forward in the FS will depend upon sediment removal volumes, site access, upland space capacity for dewatering, and disposal.

Staging Areas & Logistics

Shoreline access is also a factor. Adequate space is required to establish shoreline staging areas for equipment, water pumps, dewatering equipment, personnel, sand cap material, and offloading/onloading of barge and dredge equipment. Availability of land-based space for support operations may factor into the selection of dredge type. To protect migrating salmonids, the USFWS limits the period in which in-water construction can be performed to certain “fish windows.” Dredging can also be limited by the ability to transport, dewater, and dispose of excavated material. A significant limiting constraint for dredging is the availability of on-land property for staging and support activities, as well as disposal options (i.e., ability to transport dredged sediments to the disposal site at a rate equivalent to that of the dredging production rate).

Resuspension Potential

A major consideration for dredge design is the capability for removing targeted sediments with a minimum amount of sediment resuspension and loss during dredging (Anchor 2003; Averett 1997; Averett et al. 1999; Havis 1988). Sediment resuspension is unavoidable to some extent, regardless of the type of dredge employed, but can be minimized with operational techniques (e.g., controlling the dredge speed or cycle time). Although several specialty dredges (Cable Arm™ Bucket, Bonacavor) have been developed to reduce sediment resuspension, proper operation by an experienced contractor is an important factor to minimizing contaminant loss. The degree of sediment resuspension is also dependent on site conditions and variables, including sediment properties and size fractions (ability to resuspend), river flow hydraulics and hydrodynamics (extent of offsite transport), and ambient water quality (chemical partitioning into the water column). Data recently compiled for Scenic Hudson (Cleland 2000) and the Los Angeles Contaminated Sediments Task Force (Anchor 2003) determined that hydraulic and pneumatic dredges generally resuspend less sediment than mechanical dredges at the point of dredging. However, this benefit is offset by the much higher water entrainment encountered in the dredged material, the difficulty in managing dissolved-phase contaminants in the dredged materials, and in many cases the greater residuals at the point of dredging.

Sediment Residuals

All in-water removal operations will leave behind some level of residual contamination after completion of dredging. Although resuspension, with subsequent resettling is one factor that can influence the residual concentrations of contaminants, other factors such as the type and size of dredging equipment, level of operator skill, positioning equipment used during dredging, and the substrate type and bottom topography all combine to influence the post-dredging residuals. Managing dredging residuals is difficult simply because the dredge operator cannot see and manage the removal operation. A commonly observed phenomenon in both hydraulic and mechanical dredging is the creation of furrows or ridges between passes of the dredge equipment. The substrate and topography can greatly influence residuals. Where bedrock or hard clay underlies contaminated sediments, complete removal to low residual concentrations is both difficult and costly. When dredging on a slope, material often slumps and flows after being undercut during a removal path, resulting in recontamination of the just-dredged area. Hydraulic dredges generate residuals when the cutterhead is placed too low in the sediment or if the rate of advancement is too fast; both causing sloughing of the side cuts.

In recent years, dredging contractors have become more experienced and sophisticated at minimizing residuals. Bid documents prepared for remedial dredging include both horizontal and vertical specifications to account for uncertainty in the dredging footprint, and often specify a minimal number of passes within the footprint to achieve complete removal. However, residuals have been observed at sites after multiple dredge passes. Overlap between dredging lanes is often required, as well as the use of computer-aided positioning equipment and software, such as WINOPS, to ensure accurate and complete coverage of the dredge footprint. Matching the appropriate equipment to the dredging conditions, coupled with water quality monitoring during removal, aids in minimizing resuspension and recontamination. Even with these controls, dredging operations can still leave behind contaminant concentrations indicative of residuals at the conclusion of operations. The design should consider procedures for residuals management as part of any dredging design, and the limitations of dredging to achieve a clean final surface should be considered as part of remedial alternatives evaluation and cleanup decision-making. In short, dredging is an imperfect technology and typically leaves some degree of residual contamination, even with the use of best practices to minimize that residual.

Application of Turbidity Barriers

Turbidity barriers are specialized equipment that can be used as an engineering control to minimize downstream transport and loss of suspended solids during dredging operations. Because of their inherent logistical difficulties, they are typically employed where experience has shown that other operational controls cannot adequately meet water quality criteria. Turbidity barriers can be placed into two categories: structural and non-structural. Structural barriers are semi-permanent or permanent features to control the movement of sediment. The most common type is the sheet pile wall, a series of interlocking steel sections driven into the sediment to the same depth below mudline. This technology is expensive but effective in rivers with strong currents and/or tidal action and very high contaminant levels. It is often used in nearshore areas for dewatering and dry excavation. Non-structural, flexible barriers include oil booms, silt curtains, and silt screens. They are less expensive, easy to set up, and more movable than the structural barriers. Oil booms are utilized where dredged material may release oil residues on the water surface. Silt curtains are impervious fabrics that block, deflect, or substantially minimize the flow of water and suspended sediments. Silt screens are semi-permeable fabrics that allow water to pass while impeding the flow of coarse- to medium-grained fractions of the suspended load. Silt screens and curtains are typically suspended by floatation devices at the water surface and secured vertically in-place by a ballast chain within the lower hem of the skirt and anchored to the river bottom. These barrier systems are relatively cheap and easy to re-locate, but are limited by water depth (less than 21 feet), strong river currents (less than 1.5 feet/sec), and tidal cycles. Tidal ranges within the Whatcom Waterway can be as much as 16 feet and limit the effectiveness of screens or curtains.

Sediment Debris

The amount and type of debris to be found in the dredge zone will influence the type of dredging equipment and affect the production rate. Examples of debris include sunken logs, large rocks, shopping carts, engine blocks, rope, chain, concrete chunks, sunken boats, propane tanks, pilings, dolphins, rip rap, and other materials. Debris may also clog hydraulic dredge cutter or suction heads and pipeline, causing an increase in resuspension and requiring a temporary shutdown to remove the obstruction, thereby slowing the production rate. Debris can also inhibit the full sealing of mechanical dredge buckets, which causes loss of sediment during the buckets vertical assent through the water column and increases the rate of resuspension. The loss of sediment and the extra time devoted to handling and disposing of debris reduces the production rate.

Equipment Availability

Availability of dredging equipment is an important consideration. A number of floating clamshell dredges and small hydraulic dredges are available in the Puget Sound region. Large construction backhoes and equipment barges are also available. However, many of the specialty dredges discussed herein are not available locally and/or would require transport to the area or fabrication of new dredging equipment and a period of time to acquire operating experience. Conditions within the Whatcom Waterway site are not expected to require specialty equipment.

Dredge Accuracy and Removal Rates

Dredging accuracy is of significant importance in environmental dredging projects to ensure removal of contaminated sediments, minimize the volume of uncontaminated sediments removed, and minimize the number of passes required. Recent advances in dredging technology have included high-precision GPS location control. Several differential GPS units are used in the dredging operation, and placed on the barge and the dredge bucket or hydraulic cutterhead itself to provide a three-dimensional, real-time orientation of the equipment. High-resolution measurements provide the operator with real-time, sub-meter location precision and accuracy. These data, coupled with computer location software, allow the operator to know: (1) exactly where the dredge is collecting sediment from, (2) the amount of overlap needed to remove a swath of sediment, and (3) the exact depth of each dredge cut. In the past, system inaccuracies required remedial designs to operate on the order of 4-foot dredge prisms. With precision equipment and navigational aids, dredge operators can consistently operate to depth prisms of 0.5 foot or less with reliable accuracy. Removal efficiency is the capability for removing the target contaminated sediment layer in a single (or minimum number of) pass(es) with the dredge equipment, while minimizing the quantity of over dredged material to be treated and disposed. The costs and schedule for environmental dredging are largely dependent on the amount of sediment to be removed and the rate of removal. The rate of removal is affected by several variables, including water depth, type of excavation (wet or dry), the number and sizes of dredges used, the dredge operational speed, and the capacity of transport barges for mechanical and/or sediment dewatering, and water treatment systems for hydraulic dredging. Uncontrollable factors also affect the removal rate, such as passing ships and navigation restrictions, adverse weather conditions, unexpected presence of debris or bedrock, noise level restrictions, seasonal "fish window" restrictions, and tribal fishing rights.

Management of Entrained Water

Another decision factor is water management, and the practicality of managing large volumes of water associated with dredged material that will require collection and treatment prior to discharge of return flow to the Bay. The water volumes range from small amounts of free water and drainage arising from mechanically-dredged sediment to significant continuous volumes associated with return flow from a hydraulic dredge.

Hydraulic dredging would create large quantities of dredge slurry and entrained water. That contaminated water would ultimately be discharged back to Bellingham Bay. Assuming typical operating parameters (i.e., a controlled 2,000 cubic yard per day dredge production rate, a 10:1 water to sediment ratio and either one or two dredge units operating simultaneously) the hydraulic dredging would result in discharge of between 4 million and 8 million gallons per day of produced dredge waters to the Bay. The ability to treat and dispose of this continuously-generated water in a cost-effective and environmentally sound manner is a pre-requisite for the successful application of hydraulic dredging for large project areas. In some cases, the conditions under which hydraulic dredging and water management are performed can result in biogeochemical mobilization of bound sediment contaminants, such as at the Lavaca Bay, Texas dredging project. Bloom and Lasorsa (1999) report that high concentrations of methylmercury were released during separation of dredged material and entrained water from a hydraulic dredging event. The amount of methylmercury released was greater than could be accounted for by sediment pore water or bound methylmercury, suggesting that methylation of mercury was promoted by the conditions associated with the dredging and phase separation activities.

Dredging programs must consider the quantity and quality of waters to be generated, and must provide for management of water quality impacts to maintain the effectiveness of the dredging activity. In some cases dredging is not effective because these secondary impacts cannot be reliably controlled.

Contractual Issues and Operator Experience

The need exists for appropriately structured cleanup contracts, skilled operators, and preparation time for the operators to become familiar with the site. Adequate site characterization from the RI/FS process is typically supplemented during remedial design, and in some cases during the project bidding process. The characterization data relevant to dredging contracts include (1) the vertical extent of contaminated sediment requiring removal, (2) ship traffic and current/tidal ranges, and (3) the expected range of sediment physical properties (i.e., density, grain size, plasticity). These factors affect contractor costs, equipment selection and dredging procedures. The contractual agreements between the project engineer and the general contractor/dredge contractor are equally important. The emphasis should be carefully placed on the quality of removal, environmental protection and cost-effectiveness of the whole cycle of dredging, transport and disposal, not solely on the speed/cost of removal. Otherwise, cost-cutting measures taken at the point of dredging can result in significant environmental problems and cost control issues with the downstream activities (i.e., dredge material disposal, residuals management). During the selection process, the experience and skill of equipment operators should be evaluated and included as part of a contractor pre-qualification process.

In addition to selecting skilled and experienced contractors to conduct a dredging operation, operator experience can be managed in part by performance-based contracts to help ensure compliance with environmental monitoring and criteria. These contracts should allow the contractor flexibility to select or modify dredge equipment in order to meet the project objectives, but require compliance with the overall project objectives, including water quality goals. In the case of Puget Sound area projects, such as the Sitcum Waterway and Wyckoff/West Eagle Harbor projects, the contractor was aware of the project objectives, given flexibility to meet these objectives, and held accountable through performance-based contracting. Coupled with performance-based contracting and skilled operators is the requirement for skilled and knowledgeable independent oversight, as well as an adequate water quality monitoring program. Project oversight and contract management provide independent verification of achievement of project goals and objectives. The water quality monitoring program provides immediate feedback on the overall performance to both the dredging and oversight contractors.

5.5 Sediment Disposal and Reuse Options

If sediments are to be removed by dredging and not contained on site, then they must be disposed off-site or beneficially reused. Potential disposal and reuse options are described below.

5.5.1 Subtitle D Landfill Disposal

Dredged sediments containing elevated constituent levels can be disposed at permitted upland landfills. The solid waste landfills that manage refuse from households and businesses are known as Subtitle D facilities, because they are regulated under Subtitle D of the federal solid waste regulations. These landfills require “daily cover” to be placed over solid wastes at the end of each day of filling. Contaminated soils and sediments like those of the Whatcom Waterway can be used as daily cover at these facilities. This type of disposal is described in this Feasibility Study as “Subtitle D Landfill Disposal.”

A recent study by the US Army Corps of Engineers (USACE, 2003) identified upland disposal in a commercial landfill as the preferred alternative for management of contaminated sediment in Puget Sound. A typical process would include offloading sediments from the point of dredging to an upland staging area, loading sediments into transportation from an upland staging area, transportation of the sediments to the landfill, and disposal in the landfill. For low-solids sediments, it may be desirable to decrease the volume and mass of sediments disposed in the landfill through dewatering, provided that this can be accomplished cost-effectively and in an environmentally protective manner. The exact management and treatment train depends on the volume of sediments to be disposed, the sediment properties, the required production rate, and the dredging method.

The Disposal Siting Documentation Report identified the Roosevelt Regional Landfill as a potential upland disposal site. The landfill is located in Roosevelt, Washington approximately 220 miles by rail from Bellingham. For use of this disposal site, dredged sediments would be offloaded from barges and loaded into railcars for transport to Roosevelt. The offloading could take place in Bellingham at a facility constructed to accommodate the sediment offloading and shipment, or at an already constructed facility, such as those in Seattle and Tacoma.

The Columbia Ridge landfill located in eastern Oregon is also available for management of dredged materials, and like the Roosevelt landfill is capable of managing sediments containing free liquids. The current capacity of the Roosevelt Regional Landfill and the Columbia Ridge landfill are on the order of several million cubic yards of sediment.

Other Subtitle D disposal sites located in Western Washington are generally limited to the management of materials that pass paint-filter tests for free liquids. This results in additional requirements for dewatering and/or solidification of the dredged materials for shipment to these alternative facilities.

The Subtitle D disposal option was retained for further evaluation in the Feasibility Study. Remedial alternatives development and cost estimation were based on pricing for transportation and disposal of materials to landfills permitted to accept wet dredged sediment materials.

5.5.2 New Upland Disposal Sites

For development of remedial alternatives and cost estimates, only existing facilities permitted to accept impacted sediments were used. It is possible that a new upland disposal site may be developed by a third party and would be available for use for sediment disposal.

An example of a potential new upland disposal site is the analysis conducted during the Bellingham Bay Demonstration Pilot of the Whatcom-Skagit Phyllite Quarry. The Whatcom-Skagit Phyllite Quarry is a soon to be closed quarry located approximately 15 miles from the site. If used for disposal of dredged sediments, a Washington Solid Waste permit would likely be required to construct a disposal facility in the quarry. The quarry would be graded, and a liner and leachate collection system constructed. Dredged sediments would be offloaded from barges in Bellingham, potentially dewatered, and transported to the quarry. After all sediments had been placed in the quarry, the sediments would be graded, and a cover constructed over the sediments. A wetland similar to those surrounding the site may be constructed over the cover. In the long term, leachate from the sediments would be collected, treated if necessary, and discharged to the City of Burlington sewer system. The capacity of the Whatcom-Skagit Phyllite Quarry was assessed at approximately 200,000 to 240,000 cubic yards of sediment. The final unit costs for disposal at the Phyllite Quarry would likely be similar to or in excess of Subtitle D disposal options. The availability and public acceptability of the option are not certain.

Other disposal facilities not currently certified as Subtitle D landfills could alternatively be suitable for use at the time of project implementation. These could potentially include some disposal facilities in British Columbia that are not directly subject to U.S. regulations, but rather are regulated by Canadian and/or provincial regulations. Use of these types of alternative disposal facilities would need to be approved by the Department of Ecology. These types of facilities are not necessarily precluded from use during the project, but were not used for cost analysis or development of remedial alternatives in the Feasibility Study.

5.5.3 PSDDA Disposal and Beneficial Reuse

In Puget Sound, the open water disposal of aquatic sediments is managed under the Puget Sound Dredged Material Management Program (DMMP). This program is administered jointly by the US Army Corps of Engineers, the US Environmental Protection Agency, the Washington Department of Natural Resources, and the Washington Department of Ecology. Under the DMMP, six aquatic disposal sites (PSDDA sites) have been created in Puget Sound, and several more outside Puget Sound. The PSDDA site typically used for Bellingham Bay maintenance dredging projects is located in Rosario Straits. The PSDDA sites are monitored by Washington Department of Natural Resources to ensure that the sediments placed in these sites do not pose unacceptable impacts in the long term.

In order to dispose of sediments in one of the sites, the sediments are first characterized to ensure that they meet the criteria for disposal at the PSDDA site. For removed sediments that exceed PSDDA criteria, alternative containment, treatment and/or disposal options must be used. The appropriate permits are obtained for the dredging work, and an application made for disposal in the PSDDA site. Washington Department of Natural Resources reviews the application and determines if the sediments may be disposed in the PSDDA site. If approved for PSDDA disposal, a Site Use Authorization will be issued. The applicant can then dredge their project and dispose of the material in the PSDDA site. A fee is paid by the applicant for use of the disposal site.

The PSDDA program has also developed guidance for the beneficial reuse of clean dredged materials. Reuse options must be compatible with the chemical and physical properties of the materials, and with applicable regulatory requirements.

5.5.4 Regional Multi-User Disposal Sites

At some point in the future, a multi-user sediment disposal site may be developed within the greater Puget Sound area. Significant efforts have been expended both within Bellingham Bay, and within the greater Puget Sound region to evaluate the potential design, location, operating procedures and long-term care requirements associated with such a facility. These efforts were supported by multiple environmental and resource agencies, and included programmatic evaluations by the Army Corps of Engineers, WDNR and other agencies. A multi-user disposal site scenario was pursued as part of the 2000 RI/FS and EIS, and was identified as an element of the preferred remedial alternative identified in those studies. However, the multi-user disposal site proved infeasible due to implementability barriers and associated costs. To date, the development of multi-user disposal sites within Bellingham Bay or Puget Sound has been unsuccessful.

There is no active proposal for development of a specific multi-user site that is likely to produce a completed site within the next three to five years. Lacking a specific regional multi-user disposal site, the regional disposal site option was not carried forward in the Feasibility Study. The potential for development of a project-specific disposal site is addressed by the Cornwall CAD and ASB CND options evaluated in the Feasibility Study.

5.6 *Ex Situ* Treatment

Treatment is a preferable remedy for long-term effectiveness under MTCA. However, with the exception of certain technologies such as dewatering and solidification, the feasibility of most treatment technologies has not yet been demonstrated for application to contaminated sediments. The Cooperative Sediment Management Program (CSMP), a consortium of federal and state agencies formed in 1994 to oversee the management of Puget Sound sediments, recently initiated a study to assess the feasibility and practicability of developing a multi-user treatment program or facility to help manage contaminated sediments in Puget Sound.

As part of the CSMP, a recent study by Ecology on the viability of sediment treatment in Puget Sound concluded that a centralized sediment treatment facility was economically feasible, though a combination of public and private capital would be required to develop such a facility (SAIC, 2001). Also as part of the CSMP, the US Army Corps of Engineers conducted a feasibility study for siting of a contaminated sediment management facility in Puget Sound, which included both disposal sites and treatment. This study concluded that because of the availability and interest from several upland landfills, that disposal in an existing commercial upland landfill provided the best approach for management of contaminated sediments expected to be generated from cleanup projects in Puget Sound (USACE, 2003). These studies and the general lack of demonstrated effectiveness of treatment of sediment indicate that treatment is not likely to be a viable option for sediments from the Whatcom Waterway, unless a new technology or capital source for a new treatment facility is identified.

Nevertheless, the treatment technologies that have been evaluated are described below. For each technology, agency technology reviews by EPA (1994 and 1999) have been supplemented with additional technology reviews performed for this project.

5.6.1 Dewatering & Volume Reduction

Sediment dewatering can include mechanical and passive methods. Mechanical dewatering involves the use of equipment such as centrifuges, hydrocyclones, belt presses, and plate and frame filter presses to remove moisture from the sediments. Passive dewatering (also referred to as gravity dewatering) involves the gravity separation of water and solids in a sedimentation basin. Treatment of wastewater generated during sediment dewatering may be required to meet water quality requirements for either discharge to a municipal wastewater treatment system, or back to surface water. Dewatering can be considered active treatment to the extent that it reduces the volume or toxicity of an impacted material.

Mechanical Dewatering

Mechanical dewatering equipment physically forces water out of sediment, and are typically paired with hydraulic removal systems. Four techniques are typically considered for dewatering dredged sediments: centrifugation, diaphragm filter presses, belt presses, and hydrocyclones.

- **Centrifugation** uses centrifugal force to separate liquids from solids. Water and solids are separated based upon density differences. The use of a cloth filter or the addition of flocculent chemicals assists in the separation of fine particles.

- **Hydrocyclones** are continuously-operated devices that use centrifugal force to accelerate the settling rate and separation of sediment particles within water. Hydrocyclones are cone shaped. Slurries enter near the top and spin downward toward the point of the cone. The particles settle out through a drain in the bottom of the cone, while the effluent water exits through a pipe exiting the top of the cone.

- **Diaphragm filter presses** are filter presses with an inflatable diaphragm, which adds an additional force to the filter cake prior to removal of the dewatered sediments from the filter. Filter presses operate as a series of vertical filters that filter the sediments from the dredge slurry as the slurry is pumped past the filters. Once the filter's surface is covered by sediments, the flow of the slurry is stopped and the caked sediments are removed from the filter. Filter presses are very costly and labor intensive.

- **Belt presses** use porous belts to compress sediments. Slurries are sandwiched between the belts, resulting in high pressure compression and shear, which promotes the separation. Flocculents are often used to assist the removal of water from the sediments. The overall dewatering process usually involves gravity-draining free water, low pressure compression, and finally high pressure compression. Belt presses can be fixed based or transportable. They are commonly used in sludge management operations at municipal and industrial wastewater treatment plants.

Mechanical dewatering is considered potentially cost-effective for application to low-solids materials such as the ASB sludges, and has been retained for consideration in the Feasibility Study for these materials. Volume reduction in the ASB sludges could significantly reduce disposal volumes, tonnages and costs. Application of mechanical dewatering to other medium and high solids materials such as the sediments outside the ASB is unlikely to be cost-effective.

5.6.2 Acid Extraction

The acid extraction process selectively extracts targeted metals while non-regulated metals theoretically remain in the treated soil or sediment. Under optimal conditions, metals can be concentrated from the process and may be suitable for recycling.

The process is semi-continuous and consists of three key treatment steps: physical separation, chemical extraction, and liquids processing. In the physical separation step, the dredged sediments are segregated at a land-based facility into various size fractions (typically using a 1/16 to 1/4 inch screen), to exclude relatively clean coarse materials such as sands and gravels from further treatment. The chemical extraction step typically consists of a multistage solvent extraction which utilizes proprietary additives in an acidic solvent to preferentially remove target metals. A slurry consisting of sediment and the acidic solvent is vigorously agitated in closed-top tanks to ensure thorough contact between the sediment and solution. Mechanical mixing and/or air sparging accomplish the agitation. The rate at which the metal ions are solubilized and enter the liquid phase is determined by controlling the residence time, solid particle size, degree of agitation, and the extraction solution composition. The optimal solvent/additives formulation, the required number of stages, and the key operating parameters are site specific and are determined by performing bench-scale treatability studies.

In the liquids processing step, the metal-laden solvent may be treated by filtration and electro-chemical processes to selectively recover the metal contaminants in a concentrated form. The solvent is treated and recycled back to the chemical extraction portion of the process.

To date, slurry extraction technology has been used at upland soil sites containing very high concentrations of target metals and much lower volumes of contaminated materials. The presence of organic materials and naturally occurring metals (e.g., iron) that are typical of Whatcom Waterway sediments are of significant concern when applying this process, and can affect performance and increase costs.

A "ballpark" cost estimate per unit of sediments treated, including upland disposal of residues is approximately $200 to $500 per cubic yard of in situ sediment (EPA, 1999). This technology was not considered effective or implementable for application at the Whatcom Waterway site.

5.6.3 Phytoremediation

Phytoremediation includes a variety of processes that use natural or genetically altered terrestrial plant species to accomplish chemical transformation, accumulation in plant tissue, and/or volatilization to the atmosphere.

In previous experimentation and pilot-scale testing specific to soils with relatively high mercury concentrations, gene isolation and introduction methods have been used to genetically engineer various plant species to accomplish such transformations. For example, strains of “hyperaccumulator” species such as Yellow poplar and cattail have been developed that release enzymes into soils, geochemically converting (over several steps) the metal compounds which are then transpired through the plant tissue, and released into the atmosphere (Phytoworks, Inc., unpublished data, 1998). The potential health hazards associated with application of this technology would need to be addressed in any full-scale operation.

Use of phytoremediation technologies within the Whatcom Waterway Area would require transfer of sediments to an upland treatment/disposal facility, and spreading of the sediments in a relatively thin layer (e.g., up to several feet thick) that would be seeded with freshwater or brackish hyperaccumulator species. Currently, field-scale phytoremediation of mercury soils has only been performed in the southeast (characterized by relatively long growing seasons), though bench-scale testing is currently underway in other areas of the U.S. Similar to the acid extraction technology, these sites have contained much higher concentrations and much lower volumes of contaminated materials than those present in the Whatcom Waterway site.

Based on these previous applications, a range of plant tissue manipulations, bench-scale laboratory analysis, and pilot-scale testing would likely be necessary to determine the feasibility of this process for application to the Whatcom Waterway site. Finally, because low-level contaminant residues could continue to persist in the treated material, the final residue may still require containment or upland landfill disposal.

A ballpark cost estimate per unit of sediments treated, including upland disposal of residues, would likely exceed roughly $200 per cubic yard of in situ sediment and the technology would require very large areas for implementation. This technology is not considered effective or implementable for application at the Whatcom Waterway site.

5.6.4 Soil/Sediment Washing

Soil/sediment washing is a water-based, volumetric reduction process whereby chemicals such as mercury are extracted and concentrated into a smaller residual volume using physical and chemical methods. Similar to the acid extraction process summarized above, an initial physical separation step is used at a land-based facility to exclude relatively clean coarse materials such as sands and gravels from further treatment. Subsequently, chemical extraction agents are added to the water-based “washing” medium, and may include surfactants, chelating agents, coagulants, flocculants, and pH modifiers. Under optimal conditions, the washing process permits concentration of hazardous chemicals into a residual liquid (water-based) product representing 10 to 30 percent of the original sediment volume. However, these volumetric reductions can become more difficult to achieve for sediments such as those within the Whatcom Waterway Area, which typically contain more than 80 percent fines. The presence of woody materials, also characteristic of subsurface sediments in the Whatcom Waterway Area, may further reduce the effectiveness of soil/sediment washing. The residual liquid (water-based) product produced by the soil/sediment washing process requires further treatment and disposal. Chemical extraction is discussed above, while thermal treatment and stabilization are described below. In some cases, the wastewater may be discharged to an off-site treatment plant or may be treated and discharged to Bellingham Bay. A "ballpark" cost estimate per unit of sediments treated, including treatment of residues, may range from approximately $100 to $500 per cubic yard of in situ sediment, depending on site conditions (EPA, 1999). Like Phytoremediation, the residual sediments are likely to contain constituent levels that would restrict reuse options and would require disposal of the treated residuals. This technology is not considered implementable or cost-effective for application to the Whatcom Waterway site.

5.6.5 Thermal Desorption

Several vendors have developed and commercialized medium-temperature thermal desorption processes for removing mercury from soils and sediments However, none of these technologies are permitted for application in the Puget Sound region. The process can recover a range of inorganic forms of mercury, if mercury recovery is performed. Lower cost forms of the technology volatilize mercury into the atmosphere.

In the higher-cost version of the process, soils/sediments are blended with a proprietary additive, which promotes decomposition of stable mercury compounds, and the blended sediments are then loaded into a batch-operated furnace for processing. Thermal processing is divided into two stages: feed drying and mercury desorption. The furnace temperature is ramped to a temperature at which moisture in the feed can be removed with minimum volatilization of mercury. During this stage, the process off gas is routed through a gas filtration system. After the feed has been dried, the furnace temperature is raised to, and held at, a temperature at which the mercury is driven off as a dry vapor. In this stage, the process gas stream is routed through a heat exchanger to condense metallic mercury from mercury vapor before the gas is routed through a gas filtration system. The operating temperature for the process typically ranges from 300 to 1,400 degrees Fahrenheit, depending on the moisture content of the soil/sediment and other site characteristics. The furnace and air handling components are typically protected by secondary containment, which operates under an air treatment system separate from that of the process air.

The medium-temperature thermal desorption process has been used successfully to remediate a range of upland soil sites containing mercury and other metals. Typically, these sites have contained much higher concentrations (e.g., hazardous waste mercury sludges) and much lower volumes of mercury-containing materials than those present in the Whatcom Waterway site. Considering the relatively high moisture content of Whatcom Waterway sediments, relative to upland soils, a "ballpark" cost estimate per unit of sediments treated, including disposal of residues, is approximately $500 to $2,000 per cubic yard of in situ sediment (EPA, 1999). This technology is not considered cost-effective for application at the Whatcom Waterway site.

5.6.6 Light Weight Aggregate Production

Several commercial ventures have developed processes that use mostly or all contaminated sediments as the raw material to produce light weight aggregate (LWA) with 30 percent less weight than regular rock but with the same strength. Typical LWA is made by heating pellets of compacted sediment (supplemented with clay or shale as required) to about 1,100 ^{o}C in a kiln. The material tends to break along fracture lines and therefore has inherent weak points.

A typically process flow consists of the following steps: 1) screen or filter dredged sediments to separate out sands, gravels, and other coarse materials; 2) grind, mix (possibly with clay or shale), and dry the material; 3) process the material through an extruder to make homogenous pellets; 4) further dry the pellets (optional); 5) process the pellets through a kiln; and 6) cool the pellets prior to transport and use.

Some of the issues that would need to be addressed in a full-scale application of LWA production include: 1) energy required to run the plant and possible use of waste heat in the drying process at a fixed plant location; 2) transportation costs; 3) kiln temperatures of 1,100 ºC may not be sufficient to destroy all organic contaminants; 4) the limited regional "market" for contaminated sediment treatment that may result in increased costs; and 5) the atmospheric release of volatile mercury from the treatment process would likely result in an unacceptable health risk. Given these parameters, a "ballpark" cost estimate per unit of sediments treated could range from approximately $100 to $200 per cubic yard of in situ sediment, depending on operating parameters, air emissions control requirements, availability of a reuse market for LWA.

Production of LWA from dredge materials is not considered implementable or cost-effective for application at the Whatcom Waterway site.

5.6.7 Plasma Vitrification

Several companies are currently developing higher-temperature processes in which contaminated sediments may be converted to a useful glass product by direct injection into the plume of a high-power, non-transferred-arc plasma torch (McGlaughlin et al., 1999). The sediments are first pretreated by conventional sorting and washing processes to remove large particles and debris, and to reduce the salt content. The sediment is then partially dewatered to produce a slurry or paste with as low a moisture content as possible while still being pumpable. Fluxing agents such as lime and soda ash are then added to adjust the final properties of the glass to be produced (melting point, viscosity, thermal expansion, and leachability). The mixture is then melted in the plasma reactor at temperatures exceeding 2,000 ^{o}C. The resulting molten glass for many sediments is granulated, producing an aggregate product which typically has low leachability. The glass product may then be used as the feedstock for a variety of products, including sandblasting grit, fiberglass, insulation fiber, roofing granules, and road aggregate. However, residual constituent concentrations can limit reuse options, and the current excess of recycled glass materials negatively affects the down-stream economics of this process. Without potential revenue from the sale of tile, this treatment process is not cost-effective. For high production facilities, a "ballpark" cost estimate per unit of sediments treated is approximately $150 to 200 per cubic yard of in situ sediment (McGlaughlin et al., 1999). This technology is not considered implementable or cost-effective for application at the Whatcom Waterway site.

5.6.8 Stabilization/Solidification

Solidification involves mixing a chemical agent with dredged sediments to absorb moisture. Portland cement, pozzolan fly ash, fly ash/Portland cement mixtures, and lime kiln dust are common additives. The chemical agent and sediments may be mixed in a pug mill or in a contained area (e.g., a roll off box or pit) using an excavator, depending upon sediment production rates and work space areas. Solidification is commonly used for sediments that have been partially dewatered by another means. Mechanically-dredged sediments can sometimes be solidified directly. Solidification is not a practical method for dewatering hydraulically-dredged sediments in the absence of thickening the solids by some other means, because the amount of chemical agent required becomes cost prohibitive. Requirements for solidification vary depending on the requirements of the disposal site or subsequent treatment option, the properties of the dredged materials, and also on the extent of previous dewatering conducted.

A number of different companies have developed manufacturing technologies for producing construction-grade cements or lightweight aggregate materials from a wide variety of contaminated waste materials, including sediments. Using various proprietary additives and processes, metals and organic chemicals can be immobilized and sequestered within the stabilized sediment. The material can be transformed into construction-grade cement. However, stabilization is typically conducted as part of a disposal step (i.e., as pretreatment of highly-impacted materials prior to disposal) rather than as a true material reuse application.

While stabilization has been used successfully using relatively coarse soils and sediments, the fine-grained characteristics of Whatcom Waterway sediments (i.e., greater than 80 percent fines) would require the addition of sand and/or gravel material to achieve typical structural requirements. Further, the presence of woody debris and other organic materials that are typical of Whatcom Waterway sediments are of significant concern when applying this process, and can substantially affect performance and increase costs. Finally, since the stabilization process does not permanently destroy chemical contaminants, the permanence (e.g., long-term durability) of the stabilized matrix would need to be addressed in bench-scale testing.

A ballpark cost estimate per unit of sediments treated is approximately $100 per cubic yard of in situ sediment (EPA, 1999), and a large disposal area or reuse area for the solidified material would be required. Washington state regulations (MTCA requirements and State Solid Waste Management Regulations) could further limit the ability to reuse the materials as construction subgrade or controlled density fill, and would likely require the materials to be managed as a solid waste. This technology is not considered implementable or cost-effective for application at the Whatcom Waterway site.

5.7 *In Situ* Treatment

Multiple bench and pilot-scale studies have evaluated potential *in situ* treatment technologies for sediment. These have included nutrient enhanced biological degradation, chemical oxidation, and stabilization. None of these studies has proven effective to date. However, a detailed screening was conducted for each of two in situ technologies. The first is an *in situ* treatment technology specifically intended for removal of metals from impacted sediments and sludges. The second technology is a type of capping known as "reactive capping."

5.7.1 Electro-Chemical Reductive Technology

Electro-chemical reductive technology (ECRT) was originally developed in Europe. The technology is based on imposing a direct electrical current with a superimposed alternating energy current via in situ electrodes, to optimize and utilize the electrical capacitance properties of soil and sediment particles.

The technology purports to be capable of oxidizing organic chemicals *in situ*, and concurrently enhancing the mobility of metals such as mercury, resulting in metal precipitation onto the electrodes. To date, the technology has been applied at one sediment site in Europe containing elevated concentrations of mercury and other metals. However, the technology has not yet been applied on a full scale in the U.S.

A pilot test of ECRT was performed at the Log Pond area of the Whatcom Waterway site, as described in Section 7.3 of the RI Report. However, it was found to be ineffective at achieving mercury removal. This technology is not considered sufficiently effective for application at the Whatcom Waterway site.

5.7.2 Reactive Caps

Reactive capping is a developing technology that incorporates catalytic, sequestering, or blocking agents into the sediment cap design. This may be done by specification of a total organic carbon content in the applied cap, or through additions of materials that have been shown to be effective in dechlorination, sequestering of metals or recalcitrant hydrocarbons, or providing a seal against contaminant migration through a cap.

In recent Puget Sound projects, organic carbon additions have included application of granulated anthracite to the Pacific Sound Resources RA1 cap, addition of peat mixed with the sand cap in the Head of the Thea Foss Waterway project (DOF 2004), and the addition of granular activated carbon to the cap at the Olympic View Restoration Area. At the Olympic View Restoration area, high TOC materials mixed with sand was placed as part of the lower layer of an isolation cap to protect against PCBs and dioxins. This "high TOC/sand" layer was 6 inches thick. The material was not thought of as a reactive cap, but was placed as a precautionary barrier (K. Keeley, EPA, personal communication). The cap design followed the standard USACE guidance calculations for caps. According to the design document, the GAC used was a "common commercial-grade product" mixed at 4 percent by volume (1.5 percent by weight) (Hart Crowser 2002).

A major demonstration of several of the more active-addition reactive cap designs is now underway on the Anacostia River in Washington, DC (HSRC 2004). The objective of the Anacostia River demonstration project, which began field trials in spring 2004, is to provide information on the design, construction, placement and effectiveness of these augmented caps. The cap methods selected for use in the pilot demonstration included multiple augmentation materials. AquaBlok™, a commercial product designed to enhance chemical sequestering (e.g., through TOC amendments to the cap) and to reduce permeability at the sediment-water interface. AquaBlok™ is not recommended for application in saline environments. Apatite is a material added to encourage precipitation and sorption of metals. Coal and/or coke breeze materials were added because they can strongly adsorb hydrophobic organic contaminants such as PCBs.

Based on the success of the Log Pond cap at preventing migration of sediment contaminants upward through the cap, there does not appear to be a need to apply reactive cap technology at the Whatcom Waterway site. Reactive cap technology was not retained for application at the site.

5.8 Summary of Retained Technologies

As described in Sections 5.2 through 5.7 above and as indicated in Table 5-1, the following remedial technologies were considered sufficiently effective, implementable, and cost-effective for use in the development of remedial alternatives:

- **Monitored Natural Recovery:** The effectiveness of natural recovery at reducing surface concentrations of mercury within the site has been demonstrated. The use of Monitored Natural Recovery as part of a remedial strategy for the site is considered effective and implementable. This technology is retained for use in the development of remedial alternatives.

- **Containment by Capping:** Capping is effective, implementable and cost-effective, and is retained for use in the development of remedial alternatives. Land use, navigation patterns and physical factors will be considered in the discussion of capping feasibility for specific site areas.

- **On-Site Containment:** Section 5.3 addresses potential on-site containment options for contaminated sediments that maybe generated during site remediation. These include the development of a CAD site adjacent to the Cornwall Avenue Landfill and the development of a CND within the ASB. These containment options are retained for use in the development of remedial alternatives.

- **Removal by Mechanical Dredging:** Mechanical dredging using appropriate equipment is retained for use in the development of remedial alternatives. Mechanical dredging is the most commonly used form of dredging for implementation of site cleanup projects, and appropriate equipment and skilled operators are available from within the region.

- **Removal by Hydraulic Dredging:** Hydraulic dredging was retained for use in the development of remedial alternatives, particularly for potential removal of ASB sludges, or for localized work within the Whatcom Waterway. Any application of hydraulic dredging would need to provide for management of sediment debris, minimization of dredging residuals, and methods for managing produced dredge slurry and separated waters in a cost-effective and environmentally protective manner.

- **Removal by Excavation:** Excavation of sediments without overlying water is retained for use in the development of remedial alternatives for specific portions of the site such as the ASB that could potentially be dewatered. Wet excavation using an articulated dredge is also retained for consideration. This method could be used in both confined and exposed portions of the site.

- **Treatment for Volume Reduction:** For low-solids sediments such as the ASB sludges, treatment for volume reduction using centrifuges, hydrocyclones or other mechanical dewatering equipment is retained for use in the development of remedial alternatives. Treatment for volume reduction is not retained for medium to high solids sediments such as those from areas outside of the ASB.

- **Subtitle D Landfill Disposal:** Contaminated sediments may be disposed at a permitted off-site subtitle D disposal facility. This disposal option is retained by use in the development of remedial alternatives.

- **PSDDA Disposal and/or Beneficial Reuse:** In specific areas of the site, sediments may be suitable for PSDDA disposal or beneficial reuse. These disposal and reuse options are retained for use in the development of remedial alternatives.

- **Institutional Controls:** Institutional controls are effective, implementable and cost-effective and are carried forward for use in the development of remedial alternatives.

Table 5-1. Screening of Remedial Technologies

General Response Actions	Remedial Technology	Technology Retained ?	Summary of Technology Screening Decision and Factors to be Considered in Development of Alternatives
1. Institutional Controls			
	Institutional Controls and Monitoring	**Yes**	No remedial technologies are considered likely to remove 100% of the impacted sediments from the site. Prior to dredging or in-water construction projects, environmental reviews are conducted by the Corps of Engineers, the Department of Ecology, and other resource agencies. These reviews address some of the issues related to long-term institutional controls for the remedies. Additional monitoring and institutional controls are appropriate to maintain the effectiveness of the remedy. Appropriate institutional controls will be developed to ensure maintenance of remedy protections in the future, potentially including updates to waterway designations, harbor area designations and/or use authorizations. Information documenting site remedial actions may be recorded in County property records, or in records maintained by the State for state-owned aquatic lands.
2. Natural Recovery			
	Monitored Natural Recovery	**Yes**	The data documented in the site Remedial Investigation indicate that natural recovery has been effective in reducing surface sediment concentrations in many areas of the site. MNR has been successfully applied at other Puget Sound area sites and may be appropriate for application at the Whatcom Waterway site in areas where land use and navigation conditions do not conflict with its use, and where monitoring and modeling demonstrate its effectiveness.
	Enhanced Natural Recovery	No	Enhanced natural recovery could be used at the site to enhance the restoration time-frame of areas where monitored natural recovery is occurring but has not yet achieved remedial objectives. However, the Feasibility Study will use MNR and Capping for alternatives development, in order to consolidate the number of remedial alternatives evaluated.For purposes of the FS, the use of ENR will be considered a potential enhancement of MNR.
3. Sediment Containment			
	Capping In Place	**Yes**	Capping has been used successfully within the Log Pond portion of the site to address imapacted sediments there, and has been successfully implemented at other sites within Puget Sound. The costs of capping are typically lower than those for sediment removal and treatment, disposal, or containment in newly constructed on-site facilities. Capping may be applied either for 1) in-situ capping, 2) capping after partial removal actions, or 3) management of dredge residuals. Capping decision factors are discussed in Section 4.
	Confined Nearshore Disposal	**Yes**	Confined nearshore disposal options have been successfully implemented at other sites within the Puget Sound region. The use a CND facility for sediment management was also previously evaluated for application at the Whatcom Waterway site. Georgia Pacific proposed the construction of a CND facility within the ASB as part of the 2002 Supplemental Feasibility Study. This technology has been carried forward for the development of remedial alternatives. Other CND facilities that were screened out during previous Bellingham Bay Pilot evaluations are not carried forward in this Feasibility Study.
	Confined Aquatic Disposal	**Yes**	Confined Aquatic Disposal options have been successfully implemented at other sites within the Puget Sound Region. The use a CAD facility for sediment management was also previously evaluated for application at the Whatcom Waterway site. The development of a CAD facility adjacent to the Cornwall Avenue Landfill was identified as the preferred alternative in the 2000 EIS. This technology has been carried forward for the development of remedial alternatives. Other CAD facilities that were screened-out during previous Bellingham Bay Pilot evaluations are not carried forward in this Feasibility Study.

Table 5-1. Screening of Remedial Technologies

General Response Actions	Remedial Technology	Technology Retained ?	Summary of Technology Screening Decision and Factors to be Considered in Development of Alternatives
4. Sediment Removal Methods			
	Mechanical Dredging	**Yes**	Mechanical dredging is the most widely used technology for removing sediments during navigational and cleanup dredging in the Puget Sound region. Mechanical dredging expertise and equipment are available locally. Dredging decision factors are discussed in Section 4.
	Hydraulic Dredging	**Yes**	Hydraulic dredging may be suitable for application in specific areas of the site, or with specific disposal options. If applied for general remediation of the site, hydraulic dredging may produce between 4 and 8 million gallons per day of impacted water that must be treated and discharged to the sanitary sewer and/or Bellingham Bay. The application of hydraulic dredging is considered most implementable for the ASB sludges, where the removal could be constructed using a closed-loop water management system prior to final water treatment and disposal. Hydraulic dredging may also be suitable for use in localized site areas where overall water generation can be minimized. Finally, hydraulic dredging could be used with the ASB CND option, provided that design evaluations confirm the ability to manage debris, dredge residuals and generated waters. Other dredging decision factors are discussed in Section 4.
	Excavation	**Yes**	Excavation without overlying water can not realistically be used for remediation of the majority of the site. However, the enclosed nature of the ASB area may allow for excavation of the ASB sludges, or for excvation of dredge residuals remaining after mass sludge removal. Any application of excavation removal would need to address dewatering methods for the area to be excavated. The use of excavator dredges for in-water dredging is also considered feasible, but these dredge methods are considered as a subset of the mechanical dredging options discussed above.
5. Disposal and Reuse Options (Section 4.3)			
	Subtitle D Disposal Sites	**Yes**	The use of Subtitle D disposal has been successfully applied to navigation dredging and remediation dredging at multiple sites within the Puget Sound Region. At least two regional landfills are available that can accept wet materials typically generated at dredging projects, and both of these landfills have sufficient capacity for use during the project. Other Subtitle D landfills are available within the region that may accept dewatered or solidified dredge materials.
	New Upland Disposal Sites	No	The development of a new upland disposal site is not carried forward for development of remedial alternatives. The costs of developing a new upland disposal site are likely to be similar to or greater than upland disposal in an existing Subtitle D facility. If a suitable facility is developed by a third party prior to project implementation, then it can be consdered at the time of project remedial design, permitting and/or contracting. However, no suitable disposal sites were identified at the time of RI/FS preparation as being under development with anticipated permit flexibility and disposal capacity appropriate for management of Whatcom Waterway dredge materials.
	PSDDA Disposal and/or Beneficial Reuse	**Yes**	Procedures for management of sediments under the PSDDA program are well developed, and are retained for consideration for those materials that meet or are likely to meet PSDDA program requirements. Beneficial reuse of certain materials may also be appropriate, especially clean sand and stone materials from the ASB berms. Such materials could be reused as part of cleanup and/or habitat enhancement actions within Bellingham Bay. PSDDA disposal and/or beneficial reuse are retained for use in the development of remedial alternatives.
	Regional Multi-User Disposal Sites	No	To date, no regional multi-user disposal sites have been developed, and no sites are proposed at this time that are considered likely to be available at the time of project implementation.

Table 5-1. Screening of Remedial Technologies

General Response Actions	Remedial Technology	Technology Retained ?	Summary of Technology Screening Decision and Factors to be Considered in Development of Alternatives
6. Ex-Situ Sediment Treatment			
	Dewatering & Volume Reduction	**Yes**	Commercially-viable technologies are available for dewatering and volume reduction of low-solids materials such as the ASB sludges. For low-solids materials, these technologies may be cost-effective and may substantially reduce overall disposal requirements. These technologies are not considered necessary or cost-effective for pre-treatment of medium- and high-solids sediments that are to be disposed in subtitle D facilities capable of accepting wet materials. The use of other subtitle D facilities that can accept only dry materials would require application of dewatering or solidification methods prior to transportation and disposal.
	Acid Extraction	No	This technology is costly and has not been successfully applied at large sediment sites. The treatment would not address organic contaminants, and would not remove the need for sediment disposal following treatment. This technology is least effective for fine-grained sediments such as those at the Whatcom Waterway site.
	Phytoremediation	No	Phytoremediation has not been successfully implemented on a large scale for management of dredged marine sediments containing both organic and inorganic contaminants. The technology would require a large land area for treatment, and the residuals would likely require subsequent disposal, along with plant matter produced during the phytoremediation process, increasing overall disposal requirements.
	Soil/Sediment Washing	No	Soil washing is least effective on fine-grained sediments such as those present at the Whatcom Waterway. This technology has not been successfully applied at similar sediment sites. The process would generate large volumes of contaminanted water requiring subsequent treatment and disposal to Bellingham Bay. Treated residuals would likely require disposal, limiting the overall benefit of this technology. Costs of the technology are higher than those for Subtitle D disposal.
	Thermal Desorption	No	There are no permitted mobile or fixed facilities in the Puget Sound region that are currently capable of conducting thermal desorption of Whatcom Waterway sediments. To avoid potentially harmful air emissions of mercury, thermal desorption would require the use of expensive air emissions controls. The projected costs for thermal treatment including appropriate emissions controls are substantially greater than those for Subtitle D disposal.
	Light-Weight Aggregate Production	No	There are no commercially viable facilities for the production of light-weight aggregate from dredged materials. Any new facility would require air emission controls to prevent potentially harmful emissions of mercury. There is no existing market for light-weight aggregate produced from dredged materials. The estimated costs for light-weight aggregate production are estimated to substantially exceed those of subtitle D disposal.
	Plasma Vitrification	No	Plasma vitrification could be used to convert dredged sediments to a glass matrix. The treated residuals could then be managed similar to recycled glass. However, residual contaminants will remain in the vitirified matrix, limiting potential reuse options. Currently there is no market for vitrified sediment residuals in the Puget Sound area. The costs of vitrification are substantially greater than those of Subtitle D disposal.
	Stabilization/Solidification	No	Stabilization/solidification as a pre-treatment for Subtitle D disposal is not carried forward, due to the availability of disposal sites permitted to accept wet dredge materials. It could be appropriate to use the technology if alternative disposal sites are used that cannot accept wet sediments. Due to residual contamination and the presence of biodegradable woody materials in the Whatcom Waterway sediments, reuse of the stabilized materials as soil amendments or construction subgrade is not considered practicable. Washington State Solid Waste Handling regulations may require stabilized materials to be managed as a solid waste. Therefore, stabilization/solidification as a stand-alone technology is not carried forward for development of remedial alternatives.

Table 5-1. Screening of Remedial Technologies

General Response Actions	Remedial Technology	Technology Retained ?	Summary of Technology Screening Decision and Factors to be Considered in Development of Alternatives
7. In-Situ Treatment			
	Electro-Chemical Reduction Technology (ECRT)	No	ECRT was pilot-tested in the Log Pond and was found to be ineffective. The technology has not been successfully implemented for treatment of metals-impacted sediments on a scale similar to that at the Whatcom Waterway site. The technology does not address organic contaminants.
	Reactive Caps	No	Reactive capping technology remains under development, and has not been applied for on a full scale for metals-impacted sediments in marine environments. Reactive caps have been applied mainly for reducing the mobility of organic contaminants. Previous capping of the Log Pond demonstrated that standard thick capping methods can prevent upward migration of both inorganic and organic constituents. The incremental costs associated with the use of reactive cap designs are not considered appropriate given the preliminary nature of the technology for metal-impacted marine sediments and the success of standard thick-capping methods.

6 Description of Remedial Alternatives

This section includes a description of the eight remedial alternatives. The alternatives were developed using the technologies selected during the technology screening (Section 5). Table 6-1 provides a concise summary of the remedial alternatives and the technologies applied from Section 5. The information in this section provides for each of the alternatives:

- a detailed description of the cleanup actions performed in each portion of the Site;
- a discussion of the management options used for dredged materials generated by the cleanup action;
- a summary of the costs and schedule of the cleanup alternative;
- a discussion of potentially significant changes to existing habitat conditions associated with implementation of the cleanup action; and
- land use and navigation considerations relevant to the cleanup action.

Table 6-1 Concise Summary of Remedial Alternatives & Technologies Applied

Alternative Number	Probable Cost ($million)	Institutional Controls	Monitored Natural Recovery	Containment	Removal & Disposal	Treatment	Reuse & Recycling
Alt. 1	$8	Yes	Yes	Yes	—	—	—
Alt. 2	$34	Yes	Yes	Yes	—	—	—
Alt. 3	$34	Yes	Yes	Yes	—	—	—
Alt. 4	$21	Yes	Yes	Yes	Yes	—	—
Alt. 5	$42	Yes	Yes	Yes	Yes	Yes	Yes
Alt. 6	$44	Yes	Yes	Yes	Yes	Yes	Yes
Alt. 7	$74	Yes	Yes	Yes	Yes	Yes	Yes
Alt. 8	$146	Yes	Yes	Yes	Yes	Yes	Yes

Table 6-2 provides a detailed description of each of the eight remedial alternatives described in this section. Figures 6-1 through 6-9 illustrate the design concept of each of the alternatives. Detailed cost and engineering assumptions are provided in Appendices A and B.

6.1 Alternative 1

Alternative 1 uses containment, monitored natural recovery and institutional controls to comply with SMS cleanup levels and MTCA cleanup requirements. Alternative 1 is illustrated in Figure 6-1. Alternative 1 makes the least use of active remedial technologies of all of the evaluated alternatives.

6.1.1 Actions by Site Unit

Cleanup actions under Alternative 1 are described below by site area. The application of active cleanup measures and institutional controls is detailed in Table 6-2 for each Site Unit:

- **Outer Whatcom Waterway (Unit 1):** Under Alternative 1, no dredging or capping will be performed in the outer portion of Whatcom Waterway. Surface sediments in this area currently comply with SMS criteria. Subsurface impacted sediments would remain in place beneath the clean surface sediments. Some reduction in waterway depth would result under this alternative. Future channel maintenance would likely be restricted beneath elevations of approximately 26 feet below MLLW in order to avoid resuspension of impacted subsurface sediments. This depth restriction would need to be addressed in Waterway planning and site institutional controls.

- **Inner Whatcom Waterway (Units 2 & 3):** As with the Outer Whatcom Waterway, no dredging or capping would be performed in the Inner Whatcom Waterway under Alternative 1. The majority of this area has naturally recovered, with some surface contamination remaining in nearshore berth areas along the Colony Wharf portion of the Central Waterfront site. Additional recovery time will be required to achieve full restoration of this area. Reductions in waterway depths will accompany the use of natural recovery in the Inner Whatcom Waterway areas. The effective waterway depth will vary as shown in Figure 6-1. Additional recovery modeling would be required as part of Cleanup Action Plan development and/or remedial design to verify the applicability of natural recovery for this area.

- **Log Pond (Unit 4):** The Log Pond area was previously remediated as part of an Interim Action implemented in 2000. Subsequent monitoring has demonstrated the protectiveness of the subaqueous cap, and the effectiveness of habitat enhancement actions completed as part of that project. Actions in this area will be limited to enhancements to the shoreline edges of the cap, to ensure long-term stability of the cap edges. These enhancements are described in Appendix D of this report.

- **Areas Offshore of ASB (Unit 5):** Exceedances of site-specific cleanup goals within Unit 5-B will be remediated using sub-aqueous capping. Appendix C describes the design concept for this area, including methods to maintain cap stability in a manner compatible with anticipated permitting requirements. The remaining areas of Unit 5 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas at this time. Additional evaluations of sediment stability will be conducted as part of engineering design. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels. Additional measures will be taken in this area only if engineering design evaluations indicate that such measures are required.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The area south of the barge docks at the Bellingham Shipping (Units 6-B and 6-C) contains exceedances of SMS cleanup levels. This area will be remediated using a deep-water sub-aqueous cap. Final water depths in this area will be greater than -18 feet MLLW in most areas, consistent with shoreline infrastructure and navigation uses historically conducted there. The cap will be constructed of coarse granular materials and will be designed to resist potential prop-wash erosion effects. The remaining portions of Unit 6 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **Starr Rock (Unit 7):** Sediments in the Starr Rock area currently comply with site-specific cleanup levels. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **ASB (Unit 8):** The sludges within the ASB will be remediated using a thick sub-aqueous cap. Prior to cap placement, the treatment equipment (aerators, weirs, etc.) would be removed from the ASB. The conceptual design for the cap includes a nominal 3-foot layer of sandy capping material, with coarse materials placed in nearshore areas where wind-driven wave action may be significant. If the ASB is to be used for future stormwater/cooling water treatment, then the ASB would need to either remain connected to the current GP-owned outfall, or be provided with an alternate, appropriate-sized discharge outfall. Other modifications may be required depending on planned future uses.

6.1.2 Sediment Disposal

No sediment dredging is included in Alternative 1. All impacted sediments are managed in-place using containment technologies (capping) and monitored natural recovery. No sediment disposal sites are required under this alternative.

6.1.3 Costs & Schedule

Alternative 1 is the lowest cost of the eight evaluated alternatives. The total probable cost of Alternative 1 is $8 million. Most of this cost is associated with the capping of the ASB sludges and the two impacted harbor areas. Additional costs are included to provide for long-term monitoring of capping and natural recovery areas (Appendices A and B).

The construction activities in Alternative 1 can likely be completed within a single construction phase. The capping activities in the two impacted harbor areas would be completed during appropriate times of the year when the potential for impacts to juvenile salmonids is minimized. These construction "fish windows" are typically specified as part of project permitting requirements. Because the ASB area is not connected to Bellingham Bay, the capping activities within the ASB will not necessarily be time-limited by the "fish windows".

Monitoring of capped and natural recovery areas will occur under Alternative 1. Previous recovery analyses performed as part of the Remedial Investigation suggest that 5 and 10 years may be required for the sediment areas near the Colony Wharf portion of the Central Waterfront site. Site-specific recovery modeling would be required as part of Cleanup Action Plan development or remedial design to verify the effectiveness of this alternative. Appendix A includes unit cost and volume assumptions for Alternative 1.

6.1.4 Changes to Existing Habitat Conditions

Significant changes to existing habitat conditions that will occur as a result of implementing Alternative 1 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 1 does not change habitat conditions in the Outer Whatcom Waterway.
- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 1, no dredging is conducted within the Inner Whatcom Waterway areas, and additional shoaling would occur as part of monitored natural recovery. These processes result in preservation and enhancement of the quantity of shallow-water aquatic habitat.
- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in

changes to substrate type and elevations in shoreline edges of the cap.

- **Areas Offshore of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with the Bellingham Bay Comprehensive Strategy which identifies the development of "habitat benches" along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. Alternative 1 does not result in any changes to habitat conditions in Units 5A and 5C.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) is to be constructed in deep water and is not expected to significantly modify existing habitat quality. Alternative 1 does not involve any changes to habitat conditions in Unit 6A.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 1 do not modify existing habitat conditions at Starr Rock.

- **ASB (Unit 8):** Alternative 1 does not change the existing habitat conditions for the ASB. The ASB sludges will be capped, and this area will remain isolated from Bellingham Bay.

6.1.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 1 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 1 conflicts with existing and planned navigation uses in the Outer Whatcom Waterway. The presence of residual impacted sediments will impact the effective water depth of the terminal area. Current depths range from about 30 feet to over 35 feet below MLLW, but dredging will be required in the future to maintain navigation depth. Such dredging would resuspend impacted sediments unless the dredging were precluded below the current mudline. This would effectively limit the usable and maintainable water depth in this area to a minimum of approximately 25 feet below MLLW.

- **Inner Whatcom Waterway (Units 2 & 3):** The Inner Whatcom Waterway area has highly variable mud-line elevations. Shoaling is present particularly at the head of the waterway (near the Roeder Avenue bridge) and along the berth areas of the Central Waterfront shoreline. Effective water depths (the usable water depth along the current pierhead line) in this area vary from about -7 feet MLLW to areas that are exposed at low tide. The use of natural recovery as the remedial strategy for these areas under Alternative 1 would limit usable water depths to current conditions, with an additional measure of shoaling required to permit continuance of natural recovery and protect against resuspension of underlying contaminated sediments. Future docks or floats could be constructed in deeper waterway areas, however; the portion of the Waterway useable for navigation would be significantly less than under other project alternatives, resulting in conflicts in some areas with planned navigation and land use improvements (section 4.1.2). Further, Alternative 1 does not stabilize Inner Whatcom Waterway shorelines, resulting in potential additional use limitations in unstable shoreline areas.

- **Log Pond (Unit 4):** Consistent with property restrictive covenants, the uses of the Log Pond have been restricted to uses that do not expose capped sediments. This remains unchanged under this alternative and is consistent with planned land uses in nearby areas. Public access (i.e., shoreline promenade) along the Log Pond shoreline is anticipated as part of future area-wide redevelopment activities.

- **Areas Offshore of ASB (Unit 5)::** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with the Bellingham Bay Comprehensive Strategy which identifies the development of “habitat benches” along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. The construction of a cap in this area using the proposed design concept does not conflict with current or planned uses of the ASB, or with navigation uses in surrounding areas. Appropriate navigation aids would likely be required in perimeter areas of the cap and habitat bench to prevent inadvertent groundings of small recreational vessels. The water depths in this area are already shallow enough that larger vessels are precluded from this area.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) will reduce navigation depths in this area by approximately 3 feet (final cap thickness to be determined in final design and permitting). This change will not preclude navigation uses in this area, but will need to be incorporated into future navigation and infrastructure planning for the area.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 1 are consistent with current and anticipated navigation and land uses at Starr Rock.

- **ASB (Unit 8):** The ASB has been identified in previous land use studies as the preferred location for development of a future environmentally sustainable marina with integrated public access and habitat enhancement features (Figure 4-4). Alternative 1 conflicts with this planned use.

6.2 Alternative 2

Alternative 2 uses monitored natural recovery, institutional controls and containment technologies to comply with SMS cleanup levels and MTCA cleanup requirements. However, unlike Alternative 1, dredging of sediments from within the Whatcom Waterway channel is conducted. These sediments are managed in a new Confined Aquatic Disposal (CAD) facility that would be developed offshore of the Cornwall Avenue Landfill. The Cornwall CAD site location was selected during the 2000 EIS after evaluation of potential alternative locations. The design concept for alternative 2 is shown in Figure 6-2.

6.2.1 Actions by Site Unit

Alternative 2 represents a modification of the preferred alternative from the 2000 RI/FS and EIS process. These analyses were based on continued industrial uses of the Central Waterfront and New Whatcom areas. These analyses also assumed that future land uses would comply with the restrictions applicable to continued maintenance of the 1960s federal navigation channel. Current zoning and land use planning have changed, necessitating re-evaluation of the site remedial alternatives.

- **Outer Whatcom Waterway (Unit 1):** Under Alternative 2, the outer portion of the waterway would be dredged to a minimum depth of 35 feet below MLLW. Where technically feasible, the dredging depths would be increased to allow dredging to the base of the impacted sediments in the channel areas. Anticipated dredge depths vary from 35 feet below MLLW to about 41 feet below MLLW. The sediments removed during this dredging would be barged to the Cornwall CAD site location, and placed within the containment facility. The sediments from Units 1A and 1B would be used in upper portions of the CAD site, and the facility would be completed as described below. Some capping may be required in areas that are not technically feasible to dredge (to be determined during remedial design and permitting). Dredging methods used for the Outer Whatcom Waterway would likely be mechanical, reducing the entrained water management concerns applicable to hydraulic dredging, and producing dredge materials with physical properties appropriate for CAD site management. Detailed dredging and construction procedures and alternatives would be evaluated in project design and permitting.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 2, sediment dredging would be performed as necessary to provide for future use and maintenance of the 1960s federal navigation channel to the head of the waterway. The 1960s federal channel boundaries specify a water depth of 30 feet below MLLW from the Port terminal area to Maple Street. A depth of 18 feet is specified from Maple Street to the head of the waterway. In the Outer Whatcom Waterway, the dredging cut would be established at an elevation at least 35 feet below MLLW. This would remove sediments where technically feasible, and would provide sufficient overdepth to allow residual sediments to be capped without impeding future maintenance of the federal channel. The design concept assumes a cap thickness of 3 feet over dredged areas with residual subsurface sediment impacts. Due to historical encroachment of shoreline fills on the federal channel boundaries, many of the Inner Whatcom Waterway shoreline areas have fill and bulkheads located near or at the pierhead line. Most of these bulkheads would require replacement and/or substantial upgrades in order to maintain shoreline stability in these areas during and after dredging. Most docks and bulkheads along the Central Waterfront shoreline were constructed historically when the channel depth was shallower (18 feet below MLLW) and these docks and bulkheads would need to be either removed or replaced in order to accommodate federal channel dredging and future use. After dredging, the effective water depth (water depth at the pierhead line) will vary with location along the shoreline. The effective water depth will be controlled mostly by the type of shoreline infrastructure (i.e., nearshore fill, docks and bulkheads) that is established there. Without substantial infrastructure investments in shoreline modifications, bulkheading and dock reconstruction, the effective water depth for the head of the waterway will be significantly less in most areas than the federal channel project depth. This alternative is inconsistent with planned use of the Inner Whatcom Waterway, as described in Section 4.2.1. Planned use of the Inner Whatcom Waterway includes providing waterfront uses that combine public access, habitat enhancement and navigation uses in a manner consistent with the current-mixed use waterfront zoning. The remedial costs of this alternative address only sediment removal. The costs of the shoreline infrastructure required to improve the effective waterway depth would be borne by area redevelopment actions.

- **Log Pond (Unit 4):** The Log Pond area was previously remediated as part of an Interim Action implemented in 2000. Subsequent monitoring has demonstrated the protectiveness of the subaqueous cap, and the effectiveness of habitat enhancement actions completed as part of that project. Actions in this area will be limited to enhancements to the shoreline edges of the cap, to ensure long-term stability of the cap edges. These enhancements are described in Appendix D of this report.

- **Areas Offshore of ASB (Unit 5):** Exceedances of site-specific cleanup goals within Unit 5-B will be remediated using sub-aqueous capping. Appendix C describes the design concept for this area, including methods to maintain cap stability in a manner compatible with anticipated permitting requirements. The remaining areas of Unit 5 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas at this time. Additional evaluations of sediment stability will be conducted as part of engineering design. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels. Additional measures will be taken in this area only if engineering design evaluations indicate that such measures are required.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The area south of the barge docks at the Bellingham Shipping (Units 6-B and 6-C) contains exceedances of SMS cleanup levels. This area will be remediated using a deep-water sub-aqueous cap. Final water depths in this area will be greater than -18 feet MLLW in most areas, consistent with shoreline infrastructure and navigation uses historically conducted there. The cap will be constructed of coarse granular materials and will be designed to resist potential prop-wash erosion effects. The remaining portions of Unit 6 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **Starr Rock (Unit 7):** Sediments in the Starr Rock area currently comply with site-specific cleanup levels. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **ASB (Unit 8):** The ASB will will be remediated using a thick sub-aqueous cap. Prior to cap placement, the treatment equipment (aerators, weirs, etc.) would be removed from the ASB. The conceptual design for the cap includes a nominal 3-foot layer of sandy capping material, with coarse materials placed in nearshore areas where wind-driven wave action may be significant. If the ASB is to be used for future stormwater/cooling water treatment, then the ASB would need to either remain connected to the current GP-owned outfall, or be provided with an alternate, appropriate-sized discharge outfall. Other modifications may be required depending on planned future uses.

6.2.2 Sediment Disposal

Unlike Alternative 1, Alternative 2 involves substantial sediment dredging. The sediments dredged from the Waterway areas will be managed by containment in a new Confined Aquatic Disposal (CAD) area adjacent to the Cornwall Avenue landfill. The design concept estimates disposal of approximately 472,000 cubic yards of sediments dredged from the Outer and Inner Whatcom Waterway areas, and an additional 113,000 cubic yards of sediments dredged from Units 1A and 1B.

The Cornwall CAD site location was identified through the Bellingham Bay Pilot process, after evaluation of balancing criteria including costs, navigation, land use and habitat factors. The CAD location was incorporated into the range of remedial alternatives discussed in the 2000 RI/FS. The principal benefit of the Cornwall location as identified under the Pilot was the ability to create nearshore aquatic habitat using the CAD design approach. The geography of the area requires initial construction of an armored containment berm, prior to placement of the dredged materials within the site. Armoring of the outer edges of the berm is required to ensure long-term stability of the completed structure under anticipated wave energy and erosion conditions.

During filling of the CAD site, the containment berms would be constructed above tidal elevations. Sediments would be loaded into the facility and allowed to consolidate. The design and permitting for the CAD site would optimize sediment handling and offloading procedures to ensure compliance with water quality criteria near the CAD site location.

After the facility has been filled to design capacity, a capping layer of clean sediments would be placed to provide the final cap surface. The capping sediments will need to be appropriately sized and the cap edges will need to be appropriately constructed to resist wave-induced erosion.

Long-term monitoring and maintenance and institutional controls for the CAD facility would be required as part of the remedy. The construction of the CAD facility would also require coordination with the Cornwall Avenue Landfill and RG Haley cleanup sites, located adjacent to the CAD site location.

6.2.3 Costs & Schedule

The probable costs of Alternative 2 are $34 million. In order of decreasing cost, this estimate addresses dredging and CAD site disposal of Waterway sediments, capping costs for the ASB and harbor areas, enhancements to the Log Pond shoreline, and provisions for long-term monitoring. Long-term monitoring costs are higher than under Alternative 1, because of the additional monitoring and periodic maintenance required for the completed CAD facility (Appendices A and B).

As described above, the costs for Alternative 2 do not include the costs for upgrading shoreline infrastructure in the Inner Whatcom Waterway as necessary to stabilize shoreline conditions and support the navigation use of the Waterway berth areas. Because the 1960s channel dimensions were never fully implemented and because of encroachment along the pierhead lines, substantial infrastructure investments would be required in shoreline areas to achieve target navigation depths and complete implementation of this alternative consistent with the requirements of an industrial channel (see Figure 4-2). These costs are associated with shoreline modifications, bulkhead replacements and dock replacements, and would need to be provided as part of shoreline redevelopment actions in order to complete the cleanup in a coordinated manner. The funding and design of these shoreline actions would need to be completed in parallel with the Whatcom Waterway cleanup in order to provide for CAD-site disposal of sediments from Waterway berth areas. Otherwise, the dredging in the Waterway would be limited by side-slope stability and construction setbacks, and would generally avoid dredging activities in berth areas. Residual sediments in the berth areas would be capped pending any future redevelopment of the shoreline area. Future shoreline modifications that involved sediment generation would likely be required to manage that sediment by upland landfill disposal. Such future costs are not included in Alternative 2.

The construction activities in Alternative 2 can likely be completed within four construction seasons. With the exception of the ASB area, work activities would be confined to appropriate “fish windows.” Because the ASB area is not connected to Bellingham Bay, the capping activities within the ASB will not necessarily be time-limited by the “fish windows.”

Monitoring of capped and natural recovery areas will occur under Alternative 2. Monitoring will also be performed at the CAD site to ensure long-term effectiveness of the sediment containment.

6.2.4 Changes to Existing Habitat Conditions

The significant changes to existing habitat conditions that will occur as a result of implementing Alternative 2 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 2 includes dredging of the Outer Waterway areas. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 2, dredging of the Inner Whatcom Waterway is conducted consistent with the boundaries of the 1960s federal channel. This requires the removal of emergent shallow-water habitat at the head and along the sides of the channel. Further, to achieve target dredge depths and navigation conditions, the shorelines must be hardened with bulkheads and other infrastructure similar to that shown in Figure 4-2. The application of this shoreline infrastructure would further reduce the existing quality of nearshore aquatic habitat within the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in changes to substrate type and elevations in shoreline edges of the cap.

- **Areas Offshore of ASB(Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of "habitat benches" along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. Alternative 2 does not result in any changes to habitat conditions in Units 5A and 5C.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) is to be constructed in deep water and is not expected to significantly modify existing habitat quality. Alternative 2 does not involve any changes to habitat conditions in Unit 6A.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 2 do not modify existing habitat conditions at Starr Rock.

- **ASB (Unit 8):** Alternative 2 does not change the existing habitat conditions for the ASB. The ASB sludges will be capped, and this area will remain isolated from Bellingham Bay.

- **Cornwall CAD Area:** Alternative 2 involves the creation of a confined aquatic disposal facility near the Cornwall Avenue Landfill. Such a facility will involve the conversion of a significant area of deep-water habitat to shallow-water habitat. The final area, elevation and quality of this shallow-water habitat will vary depending on the final design of the facility.

6.2.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 2 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 2 is consistent with current and planned land and navigation uses. The alternative allows for continued maintenance of the federal shipping channel in this area. Some infrastructure maintenance and/or upgrades would likely be required at the shipping terminal to support dredging there.

- **Inner Whatcom Waterway (Units 2 & 3):** Community land use planning efforts have emphasized the need to provide for multiple waterfront uses in the Inner Whatcom Waterway area. These uses include shoreline public access, habitat enhancement and navigation uses in a manner consistent with the mixed-use waterfront zoning. This alternative conflicts with these planned land and navigation uses. In order to support deep dredging of the 1960s industrial channel, substantial shoreline infrastructure upgrades are required. These upgrades are inconsistent with habitat enhancement actions in these same areas. Secondly, the land uses necessary to justify Corps participation in future channel maintenance likely conflict with mixed-use redevelopment and shoreline public access objectives. Some navigation uses such as transient moorage may be precluded, or may be significantly restricted in the Inner Whatcom Waterway areas. This contrasts with other FS Alternatives (i.e., Alternatives 4, 5 and 6) that assume the application of a mixed-use channel within the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Consistent with property restrictive covenants, the uses of the Log Pond have been restricted to uses that do not expose capped sediments. This remains unchanged under this alternative and is consistent with planned land uses in nearby areas. Public access (i.e., shoreline promenade) along the Log Pond shoreline is anticipated as part of future area-wide redevelopment activities.

- **Areas Offshore of ASB (Unit 5)::** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of "habitat benches" along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. The construction of a cap in this area using the proposed design concept does not conflict with current or planned uses of the ASB, or with navigation uses in surrounding areas. Appropriate navigation aids would likely be required in perimeter areas of the cap and habitat bench to prevent inadvertent groundings of small recreational vessels. The water depths in this area are already shallow enough that larger vessels are precluded from this area.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) will reduce navigation depths in this area by approximately 3 feet (to be determined in final design and permitting). This change will not preclude navigation uses in this area, but will need to be incorporated into future navigation and infrastructure planning for the area.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 2 are consistent with current and anticipated navigation and land uses at Starr Rock.

- **ASB (Unit 8):** The ASB has been identified in previous land use studies as the preferred location for development of a future environmentally sustainable marina with integrated public access and habitat enhancement features (Figure 4-4). Alternative 2 conflicts with this planned use.

6.3 Alternative 3

Alternative 3 uses a combination of institutional controls, monitored natural recovery and containment to achieve compliance with SMS cleanup levels.

Alternative 3 uses dredging to remove sediments from the Whatcom Waterway as necessary to allow use and maintenance of the 1960s federal navigation channel. These sediments are managed by creating a nearshore fill within the majority of the ASB. The portion of the ASB not required for the fill would be retained for stormwater or cooling water treatment uses. Alternative 3 is shown in Figure 6-3

6.3.1 Actions by Site Unit

Cleanup Alternative 3 represents a modification of the cleanup Alternative "J" evaluated in a previous Supplemental Feasibility Study (Anchor, 2002) after closure of the Pulp Mill and Chlor-Alkali Plant. The original evaluation of this remedial alternative was based on continued industrial uses of the ASB and upland properties adjacent to the Whatcom Waterway site. These land uses are no longer applicable (Section 4). A description of Alternative 3 by site unit follows:

- **Outer Whatcom Waterway (Unit 1):** Under Alternative 3, the outer portion of the waterway would be dredged to a minimum depth of 35 feet below MLLW. Where technically feasible, the dredging depths would be increased to allow dredging to the base of the impacted sediments in the channel areas. Anticipated dredge depths vary from 35 feet below MLLW to about 41 feet below MLLW. Under this alternative, dredging from the Outer Whatcom Waterway areas could potentially be conducted using either hydraulic or mechanical dredging. Hydraulic dredging could provide the most cost-effective initial placement of the sediments within the ASB, and may potentially reduce turbidity levels at the point of dredging. However, hydraulic dredging is not well suited for areas containing woody debris, as expected in the Waterway. Further, hydraulic dredging with a cutter-head dredge can leave significant dredging residuals, up to a foot in thickness. Finally, hydraulic dredging would create large quantities of dredge slurry and entrained water. That contaminated water would ultimately be discharged back to Bellingham Bay. Assuming typical operating parameters (i.e., a controlled 2,000 cubic yard per day dredge production rate, a 10:1 water to sediment ratio and either one or two dredge units operating simultaneously) the hydraulic dredging would result in discharge of between 4 million and 8 million gallons per day of produced dredge waters to the Bay. Mechanical dredging and hydraulic dredging would need to be evaluated during remedial design to optimize project design and ensure protection of water quality during the dredging, both at the point of dredging and at the point of disposal for any generated waters. Sediments dredged from the waterway would be contained within the ASB fill as described below.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 3, sediment dredging would be performed within the Inner Whatcom Waterway as necessary to provide for future use and maintenance of the federal navigation channel to the head of the waterway. The 1960s federal channel boundaries specify a water depth of 30 feet below MLLW from the BST area to Maple Street. A depth of 18 feet is specified from Maple Street to the head of the waterway. In the deeper portion of the waterway, the dredging cut would be established at depths at least 35 feet below MLLW. This would remove sediments where technically feasible, and would provide sufficient over-depth to allow residual sediments to be capped without impeding future maintenance of the federal channel. The design concept assumes a cap thickness of 3 feet over dredged areas with residual subsurface sediment impacts. Due to historical encroachment of the shoreline on the federal channel boundaries, many of the Inner Whatcom Waterway shoreline areas have fill and bulkheads up to or near to the pierhead line. Most of these bulkheads would require replacement and/or substantial upgrades in order to maintain shoreline stability in these areas during and after dredging. Docks may also have to be upgraded or replaced as described in Alternative 2 in order to accommodate federal channel dredging and future use. After dredging, the effective water depth (water depth at the pierhead line) will vary with location along the shoreline. The effective water depth will be controlled mostly by the type of shoreline infrastructure (i.e., nearshore fill, docks and bulkheads) that is established there. Without substantial infrastructure investments, the effective water depth for the Inner Whatcom Waterway will be significantly less in most areas than the federal channel project depth. The remedial costs of this alternative address only sediment removal. The costs of the shoreline infrastructure required to improve the effective waterway depth would be borne by area redevelopment actions.

- **Log Pond (Unit 4):** The Log Pond area was previously remediated as part of an Interim Action implemented in 2000. Subsequent monitoring has demonstrated the protectiveness of the subaqueous cap, and the effectiveness of habitat enhancement actions completed as part of that project. Actions in this area will be limited to enhancements to the shoreline edges of the cap, to ensure long-term stability of the cap edges. These enhancements are described in Appendix D of this report.

- **Areas Offshore of ASB (Unit 5):** Exceedances of site-specific cleanup goals within Unit 5-B will be remediated using sub-aqueous capping. Appendix C describes the design concept for this area, including methods to maintain cap stability in a manner compatible with anticipated permitting requirements. The remaining areas of Unit 5 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas at this time. Additional evaluations of sediment stability will be conducted as part of engineering design. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels. Additional measures will be taken in this area only if engineering design evaluations indicate that such measures are required.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The area south of the barge docks at the Bellingham Shipping (Units 6-B and 6-C) contains exceedances of SMS cleanup levels. This area will be remediated using a deep-water sub-aqueous cap. Final water depths in this area will be greater than -18 feet MLLW in most areas, consistent with shoreline infrastructure and navigation uses historically conducted there. The cap will be constructed of coarse granular materials and will be designed to resist potential prop-wash erosion effects. The remaining portions of Unit 6 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **Starr Rock (Unit 7):** Sediments in the Starr Rock area currently comply with site-specific cleanup levels. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **ASB (Unit 8):** Under Alternative 3, the ASB sludges would be contained within the existing ASB. Most sludges would simply be buried beneath the nearshore fill. However, the Alternative assumes that the sludges located in the outer portion of the ASB (the area not required for a nearshore fill) would be dredged and consolidated within the fill area. Construction sequencing would involve initial lowering of the water level of the ASB, followed by the removal of the wastewater treatment equipment (aerators, weirs, etc.). Dredging of sludges from the future edge of the nearshore fill would then be conducted. A berm would be constructed along this alignment. Finally, the remaining sludges would be dredged from the area outside of the berm, for consolidation within the new fill area. Because construction within the ASB would disrupt the bentonite sealant present along the bottom and sides of the ASB, some additional measures (in addition to lowering of the water level of the ASB during construction) may be required to prevent significant water leakage through the berm during and after construction. These actions may include driving of sheet-piling, placement of new bentonite sealant, or other measures. Some residual sludges would likely remain in the dredged area of the ASB, and these would be managed by sediment capping. If the ASB is to be used for future stormwater/cooling water treatment, then the ASB would need to either remain connected to the current GP-owned outfall, or provided with an alternate, appropriately-sized outfall. Other modifications may be required depending on planned future uses.

6.3.2 Sediment Disposal

Under Alternative 3, the sediments dredged from the Waterway areas will be managed by containment in a new sediment disposal site. Alternative 3 uses a nearshore fill design. The design concept estimates disposal of approximately 472,000 cubic yards of sediments dredged from the Outer and Inner Whatcom Waterway areas, and an additional 113,000 cubic yards of sediments dredged from Units 1A and 1B. Approximately 71,000 cubic yards of ASB sludges in the outer portion of the ASB would be consolidated in the fill area, along with the dredged sediments. Additional materials would be used to construct the containment berm within the ASB, and to cap the facility after placement of dredged sediments.

The principal remedial benefit associated with the ASB fill site is that the main ASB berm already exists, and does not need to be constructed. Secondly, the use of the ASB provides for consolidation of the ASB sludges as well as the dredged sediments from the Waterway.

Whether the Waterway dredging is conducted using hydraulic or mechanical dredging, the existing berms of the ASB facility would be maintained largely in their current configuration. A new berm would be constructed within the interior of the facility as described above.

Previous leachability studies conducted as part of the 2000 RI/FS and the PRDE investigation report (Anchor 2003) included evaluation of contaminant mobility under various conditions. Mobility of mercury was lowest in those tests under anoxic conditions. The design of the fill would place the dredged materials and ASB sludges below the elevation at which groundwater levels are anticipated to stabilize after facility construction. The elevated TOC content of the sediments and ASB sludges, combined with long-term groundwater saturation would tend to retain anoxic conditions within the impacted portion of the fill. Sediments from Unit 1A and 1B would be placed in upper portions of the fill, and clean sediments and/or soils would be placed on top of the final fill as a capping layer. The design and construction of the facility would provide for sediment and sludge consolidation.

The land created by the fill would be subject to further consolidation over time, due to decomposition of high-organic materials in the ASB sludges and the decomposition of woody materials in waterway sediments. This process would be similar to the long-term settlement that occurs in solid waste landfills. Any future use of the property would need to allow for such settlement to occur. Pile-supported foundations would likely be required for most buildings, involving penetration of the pilings through the fill materials and into underlying sandy soils. Water quality evaluations conducted during design and permitting would need to address water quality issues within the fill, to ensure long-term protection of surface waters. If maintenance of the bentonite sealing layer within the fill is required for long-term surface water protection, then penetration of this layer with foundation pilings could be subject to significant limitations or could be prohibited altogether. Future development of enclosed structures within the fill area would also be subject to requirements for under-building methane-control systems, similar to those used for buildings constructed on peat deposits or for buildings on or adjacent to municipal landfills.

Long-term monitoring and maintenance and institutional controls for the nearshore fill would be required as part of the remedy.

The construction of the nearshore fill would need to be coordinated with the activities at the adjacent Central Waterfront site. This would mainly involve ensuring that construction and any future reuse of the fill area does not adversely impact groundwater conditions within the Central Waterfront site.

6.3.3 Costs & Schedule

The probable costs of Alternative 3 are approximately $34 million (Appendix A). In order of decreasing cost, this estimate address dredging and ASB site disposal of Waterway sediments, preparation and completion of the ASB facility, capping costs for harbor areas, enhancements to the Log Pond shoreline, and provisions for long-term monitoring. Long-term monitoring costs include provisions for groundwater and vapor monitoring associated with the fill area.

The costs for Alternative 3 do not include the costs for upgrading shoreline infrastructure in the Inner Whatcom Waterway as necessary to stabilize shoreline conditions and support the navigation use of the water depth provided by the 1960s federal channel dimensions. Because the 1960s channel dimensions were never fully implemented, and because of encroachment along the pierhead lines, substantial investments would be required in shoreline areas. These costs are associated with shoreline modifications, bulkhead replacements and dock replacements, and would need to be provided as part of shoreline redevelopment actions in order to complete the project. As discussed in the companion EIS document, the funding and design of these shoreline actions would need to be completed in parallel with the Whatcom Waterway cleanup in order to provide for ASB disposal of sediments from waterway berth areas. Otherwise, the dredging in the Waterway would be limited by side-slope stability and construction setbacks, and would generally avoid dredging activities in berth areas. Residual sediments in the berth areas would be capped pending any future redevelopment of the shoreline area. Future shoreline modifications that involved sediment generation would likely be required to manage that sediment by upland landfill disposal. Such costs are not included in Alternative 3.

The construction activities in Alternative 3 can likely be completed within three construction seasons. The range of construction time requirements is 2 to 4 years, depending on dredging rates and construction sequencing. Higher dredging rates reduce the restoration time, but are logistically more difficult to maintain. For hydraulic dredging, use of high production rates significantly increases the rates of water generation requiring treatment and discharge to Bellingham Bay. With the exception of the initial and final work within ASB area, work activities would be confined to appropriate "fish windows". Because the ASB area is not connected to Bellingham Bay, some of the initial ASB preparation and the final capping activities within the ASB will not necessarily be time-limited by the "fish windows."

6.3.4 Changes to Existing Habitat Conditions

Significant changes to existing habitat conditions that will occur as a result of implementing Alternative 3 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 3 includes dredging of the Outer Whatcom Waterway areas. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 3, dredging of the Inner Whatcom Waterway is conducted consistent with the boundaries of the 1960s federal channel. This requires the removal of emergent shallow-water habitat at the head and along the sides of the channel. Further, to achieve target dredge depths and navigation conditions, the shorelines must be hardened with bulkheads and other infrastructure similar to that shown in Figure 4-2. The application of this shoreline infrastructure would further reduce the existing quality of nearshore aquatic habitat within the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in changes to substrate type and elevations in shoreline edges of the cap.

- **Areas Offshore of ASB (Unit 5)::** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of "habitat benches" along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. Alternative 3 does not result in any changes to habitat conditions in Units 5A and 5C.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) is to be constructed in deep water and is not expected to significantly modify existing habitat quality. Alternative 3 does not involve any changes to habitat conditions in Unit 6A.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 3 do not modify existing habitat conditions at Starr Rock.

- **ASB (Unit 8):** Alternative 3 involves construction of a nearshore fill within the ASB. The construction of the nearshore fill would permanently convert the majority of the ASB area from its current condition (wastewater treatment facility) to upland characteristics.

6.3.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 3 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 3 is consistent with current and planned land and navigation uses. The alternative allows for continued maintenance of the federal shipping channel in this area. Some infrastructure maintenance and/or upgrades would likely be required at the shipping terminal to support dredging there.

- **Inner Whatcom Waterway (Units 2 & 3):** Community land use planning efforts have emphasized the need to provide for multiple waterfront uses in the Inner Whatcom Waterway area. These uses include shoreline public access, habitat enhancement and navigation uses in a manner consistent with the mixed-use waterfront zoning. This alternative conflicts with these planned land and navigation uses. In order to support deep dredging of the 1960s industrial channel, substantial shoreline infrastructure upgrades are required. These upgrades are inconsistent with habitat enhancement actions in these same areas. Secondly, the land uses necessary to justify Corps participation in future channel maintenance likely conflict with mixed-use redevelopment and shoreline public access objectives. Some navigation uses such as transient moorage may be precluded, or may be significantly restricted in the Inner Whatcom Waterway areas. This contrasts with other FS Alternatives (i.e., Alternatives 4, 5 and 6) that assume the application of a mixed-use channel within the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Consistent with property restrictive covenants, the uses of the Log Pond have been restricted to uses that do not expose capped sediments. This remains unchanged under this alternative and is consistent with planned land uses in nearby areas. Public access (i.e., shoreline promenade) along the Log Pond shoreline is anticipated as part of future area-wide redevelopment activities.

- **Shoulder of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy with identifies the development of “habitat benches” along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. The construction of a cap in this area using the proposed design concept does not conflict with current or planned uses of the ASB, or with navigation uses in surrounding areas. Appropriate navigation aids would likely be required in perimeter areas of the cap and habitat bench to prevent inadvertent groundings of small recreational vessels. The water depths in this area are already shallow enough that larger vessels are precluded from this area.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** As in Alternatives 1 and 2, the cap in the barge dock area (Unit 6-B & C) will reduce navigation depths in this area by approximately 3 feet (to be determined in final design and permitting). This change will not preclude navigation uses in this area, but will need to be incorporated into future navigation and infrastructure planning for the area.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 3 are consistent with current and anticipated navigation and land uses at Starr Rock.

- **ASB (Unit 8):** The ASB has been identified in previous land use studies as the preferred location for development of a future environmentally sustainable marina with integrated public access and habitat enhancement features (Figure 4-4). Alternative 3 conflicts with this planned use. Alternative 3 permanently precludes such uses by designating the ASB area for a nearshore fill site. Future upland uses of the fill site may be subject to limitations, depending on final environmental and geotechnical analyses performed during remedial design and permitting.

6.4 Alternative 4

Cleanup Alternative 4 uses removal and upland disposal technology, in addition to institutional controls, monitored natural recovery and containment to comply with SMS cleanup levels. The alternative uses capping in-place for management of the ASB sludges. Alternative 4 is shown in Figure 6-4.

6.4.1 Actions by Site Unit

Cleanup actions are described below by site unit. Dredging activities within the Whatcom Waterway are targeted on appropriate areas to support a multi-purpose Waterway concept, including a mix of deep-draft navigation, public access, transient moorage and habitat enhancement uses. Sediments dredged from the Waterway are managed by upland disposal at appropriately-permitted off-site facilities.

- **Outer Whatcom Waterway (Unit 1):** Under Alternative 4, the outer portion of the waterway would be dredged to a depth of approximately 35 feet below MLLW. The sediments removed during this dredging would be barged to an offload facility within Port-owned property. The sediments would be transferred to lined railcars for transportation to an appropriately-permitted offsite disposal facility. The cost estimates are based on the use of Subtitle D permitted landfills that can accept wet sediments for reuse as daily cover. Other disposal facilities that have appropriate environmental permits may be used, subject to applicable regulations and logistical considerations. The costs for sediment transportation and disposal under this alternative were based on pricing for eastern Washington and eastern Oregon landfills. This does not preclude potential use of alternate locations subject to final remedy design, permitting and contractor discretion. After removal of sediments to -35 feet MLLW, a thick sediment cap would be placed over residual impacted sediments. The cap would be designed to resist erosive forces of prop wash, and to minimize the potential for aquatic wildlife exposures. Based on previous sediment testing, the sediments from Units 1A and 1B appear to be suitable for beneficial reuse or PSDDA disposal, subject to final testing and suitability determinations. These sediments could potentially be reused as part of the project for capping subgrade within the Inner Whatcom Waterway. However, the fine particle size distribution within the Unit 1A/1B sediments makes this use subject to logistical and long-term stability considerations. The Alternative 4 cost estimate assumes that Unit 1A and 1B sediments that are dredged are managed by open water disposal consistent with PSDDA program requirements. Mechanical dredging methods would likely be used for the Outer Whatcom Waterway area, as hydraulic dredging is impracticable without a large area for management of produced dredge waters and for separating entrained waters from dredge materials. Detailed dredging and construction procedures would be determined in project design and permitting.

- **Inner Whatcom Waterway (Units 2 & 3):** The design concept included in Alternative 4 assumes that the majority of the Inner Whatcom Waterway is to be managed for effective water depths of between 18 feet and 22 feet. This water depth range provides for navigation opportunities consistent with the mixed-use zoning of the waterfront properties, described in Section 4.2.1. The central portion of the waterway is dredged to depths at least 5 feet below the planned effective water depth. A sediment cap is then applied over any residual sediments, with the cap grading from a minimum thickness of 3 feet, to a maximum thickness of 6 feet near the Log Pond. Shoreline slopes would be stabilized using appropriately designed side-slopes and materials that maximize nearshore habitat quality and quantity, while maintaining stability and providing for appropriate navigation needs within the Waterway. Under Alternative 4, the emergent tideflats at the head of the waterway are preserved, and shallow-water habitat areas along the sides of the waterway are preserved and enhanced.

- **Log Pond (Unit 4):** The Log Pond area was previously remediated as part of an Interim Action implemented in 2000. Subsequent monitoring has demonstrated the protectiveness of the subaqueous cap, and the effectiveness of habitat enhancement actions completed as part of that project. Actions in this area will be limited to enhancements to the shoreline edges of the cap, to ensure long-term stability of the cap edges. These enhancements are described in Appendix D of this report.

- **Areas Offshore of ASB (Unit 5):** Exceedances of site-specific cleanup goals within Unit 5-B will be remediated using sub-aqueous capping. Appendix C describes the design concept for this area, including methods to maintain cap stability in a manner compatible with anticipated permitting requirements. The remaining areas of Unit 5 comply with site-specific cleanup goals.

No sediment capping or dredging is proposed for these areas at this time. Additional evaluations of sediment stability will be conducted as part of engineering design. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels. Additional measures will be taken in this area only if engineering design evaluations indicate that such measures are required.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The area south of the barge docks at the Bellingham Shipping (Units 6-B and 6-C) contains exceedances of SMS cleanup levels. This area will be remediated using a deep-water sub-aqueous cap. Final water depths in this area will be greater than -18 feet MLLW in most areas, consistent with shoreline infrastructure and navigation uses historically conducted there. The cap will be constructed of coarse granular materials and will be designed to resist potential prop-wash erosion effects. The remaining portions of Unit 6 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **Starr Rock (Unit 7):** Sediments in the Starr Rock area currently comply with site-specific cleanup levels. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **ASB (Unit 8):** As with Alternatives 1 and 2, the ASB will be remediated using a thick sub-aqueous cap.

6.4.2 Sediment Disposal

Sediments removed from Waterway areas under this Alternative will be managed by disposal at a Subtitle D upland disposal facility. Subtitle D facilities are commercially available, and are designed and permitted for management of solid waste. The design of Subtitle D facilities includes a liner, a cap, a monitoring network, and institutional controls and financial assurance provisions under state and federal solid waste regulations.

The design concept for Alternative 4 estimates disposal of approximately 68,000 cubic yards of sediments dredged from the Outer and Inner Whatcom Waterway areas at upland disposal sites. An additional 113,000 cubic yards of sediments dredged from Units 1A and 1B would be managed by beneficial reuse or PSDDA disposal.

Options for transportation of dredged materials to upland disposal sites include barge, truck and rail. Barge transportation can utilize alternate offloading locations located away from the site. Such offloading facilities exist in Seattle, Vancouver B.C. and elsewhere. The sediments are generally then transferred to truck or rail for final shipment to the disposal facility. Truck transportation is commonly used for small sediment volumes. Multiple intermodal yards exist around the region where truck containers can be transloaded for final rail shipment to the disposal site. However, for large sediment volumes, truck transportation results in additional traffic burdens and is less fuel efficient than rail transportation. The design concept and cost estimate assumes the placement of temporary rail improvements at the former GP mill site, and shipment of sediments directly from the site to the upland disposal site by rail. Stormwater management and "surge" stockpile areas are included in the project cost assumptions.

6.4.3 Costs & Schedule

The probable costs of Alternative 4 are approximately $21 million. The costs of Alternative 4 are the second lowest of all of the evaluated alternatives. In order of decreasing cost, this estimate addresses dredging and upland disposal of Whatcom Waterway sediments, capping costs for the ASB and harbor areas, enhancements to the Log Pond shoreline, and provisions for long-term monitoring (Appendices A and B).

The in-water construction activities in Alternative 4 can likely be completed within a single construction season. With the exception of the ASB area, and initial preparation and final demobilization of the upland sediment offload area, work activities would be confined to appropriate "fish windows". Because the ASB area is not connected to Bellingham Bay, the capping activities within the ASB will not necessarily be time-limited by the "fish windows".

Monitoring of capped and natural recovery areas will occur under Alternative 4. Because natural recovery is only applied in areas that have already achieved compliance with cleanup standards, additional restoration time would not be required.

6.4.4 Changes to Existing Habitat Conditions

Significant changes to existing habitat conditions that will occur as a result of implementing Alternative 4 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 4 includes dredging of the Outer Whatcom Waterway areas. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas in the Outer Whatcom Waterway.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 4, dredging is conducted to support planned navigation and land uses along the Inner Whatcom Waterway. This results in some conversion of shallow-water habitat to deep-water habitat. However, the proposed configuration of the multi-purpose channel implemented under Alternative 4 retains existing emergent shallow-water habitat areas at the head and along the sides of the waterway. Under this alternative, waterway shorelines are stabilized with slopes, rather than through the use of bulkheads and hardened shoreline infrastructure. This approach will increase the area and quality of nearshore aquatic habitat. In addition to the habitat effects achieved as a result of Whatcom Waterway cleanup, additional dock and bulkhead removals and shoreline stabilization work is contemplated as part of coordinated cleanup actions at the Central Waterfront site, and as part of mixed-use redevelopment of the properties along the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in changes to substrate type and elevations in shoreline edges of the cap.

- **Areas Offshore of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to likewise enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of “habitat benches” along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. Alternative 4 does not result in any changes to habitat conditions in Units 5A and 5C.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) is to be constructed in deep water and is not expected to significantly modify existing habitat quality. Alternative 4 does not involve any changes to habitat conditions in Unit 6A.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 4 do not modify existing habitat conditions at Starr Rock.

- **ASB (Unit 8):** Alternative 4 does not change the existing habitat conditions for the ASB. The ASB sludges will be capped, and this area will remain isolated from Bellingham Bay.

6.4.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 4 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 4 preserves the flexibility for deep draft waterway uses and/or institutional uses at the Bellingham Shipping Terminal. The alternative allows for continued maintenance of the federal channel in this area. Some infrastructure maintenance and/or upgrades would likely be required at the shipping terminal to support dredging there.

- **Inner Whatcom Waterway (Units 2 & 3):** As defined in previous and ongoing community land use planning efforts, the priorities for the Inner Whatcom Waterway area are to provide for waterfront uses that combine public access, habitat enhancement and navigation uses in a manner consistent with the mixed-use waterfront vision. Alternative 4 integrates cleanup actions with that waterfront vision. Infrastructure costs are reduced while simultaneously maximizing land use flexibility and improving both habitat conditions and navigation opportunities. There will be some depth limitation in the Inner Whatcom Waterway (18 to 22 feet vessel draft), but deeper draft vessels can be accommodated in the Outer Whatcom Waterway near the Bellingham Shipping Terminal. The navigation uses for the Inner Whatcom Waterway would accommodate transitional uses by tug boats and barges, though tractor tugs and ocean-going barges would be precluded (except for the Outer Whatcom Waterway areas). Compatible navigation uses consistent with the long-term redevelopment of the waterfront include access by recreational vessels, whale watching boats, intermediate-draft institutional vessels (i.e., research boats), sailing ships (i.e., most “Tall Ships Festival” vessels) and most passenger-only ferries. Under Alternative 4, the design of the Inner Whatcom Waterway would be integrated with local land-use planning efforts. Alternative 4 assumes that the 1960s federal channel will be updated at the head of the waterway to provide for integrated public access, habitat enhancement and navigation uses. By transitioning from a federal channel with its requisite use restrictions, to a locally-managed multi-purpose waterway, additional land use flexibility can be accommodated both within the channel area and also along the adjacent shorelines. Specifically, construction of navigation improvements beyond the pierhead line could be allowed, with appropriate land use planning and permitting. This enables navigation uses to be developed along-side habitat enhancements. For example, rather than constructing bulkheaded shorelines and over-water wharfs to the pierhead line and dredging for maximum usable depth in waterway berth areas, navigation structures such as floats can be located offshore of nearshore habitat benches and softened shorelines

- **Log Pond (Unit 4):** Consistent with property restrictive covenants, the uses of the Log Pond have been restricted to uses that do not expose capped sediments. This remains unchanged under this alternative and is consistent with planned land uses in nearby areas. Public access (i.e., shoreline promenade) along the Log Pond shoreline is anticipated as part of future area-wide redevelopment activities.

- **Areas Offshore of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to likewise enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of "habitat benches" along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. The construction of a cap in this area using the proposed design concept does not conflict with current or planned uses of the ASB, or with navigation uses in surrounding areas. Appropriate navigation aids would likely be required in perimeter areas of the cap and habitat bench to prevent inadvertent groundings of small recreational vessels. The water depths in this area are already shallow enough that larger vessels are precluded from this area.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The area near the barge dock area (Unit 6-B & C) will be capped as described in Alternatives 1 through 3, with a slight reduction in water depth within the capped area.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 4 are consistent with current and anticipated navigation and land uses at Starr Rock.

- **ASB (Unit 8):** The ASB has been identified in previous land use studies as the preferred location for development of a future environmentally sustainable marina with integrated public access and habitat enhancement features (Figure 4-4). Alternative 4 conflicts with this planned use.

6.5 Alternative 5

Alternative 5 uses multiple technologies to comply with SMS cleanup levels. Institutional controls, monitored natural recovery and containment are used in various portions of the site. Removal and upland disposal are used for ASB sludges and impacted sediments from outside of the ASB. The ASB sludges are treated to achieve volume reduction. Alternative 5 is shown in Figure 6-5

6.5.1 Actions by Site Unit

Under Alternative 5 dredging activities within the Whatcom Waterway are targeted on appropriate areas to support a multi-purpose Waterway concept, including a mix of deep-draft navigation, public access, transient moorage and habitat enhancement uses. Sediments dredged from the Waterway and the sludges removed from the ASB are managed by upland disposal at appropriately-permitted off-site Subtitle D facilities. Specific actions within each site unit are described below:

- **Outer Whatcom Waterway (Unit 1):** Under Alternative 5, the outer portion of the waterway would be dredged to a depth approximately 35 feet below MLLW, as with Alternative 4. The residual sediments in this area would be capped with a thick sediment cap. The cap would provide a sufficient thickness of cap material to allow for future waterway maintenance dredging, and would provide resistance against potential erosion by prop wash. Sediments removed during this dredging would be barged to an offload facility within Port-owned property, and would be transferred to for transportation to an appropriately-permitted offsite disposal facility. The sediments from waterway Units 1A and 1B are managed by PSDDA disposal, as in Alternative 4. Mechanical dredging methods would likely be used in the Outer Whatcom Waterway area.

- **Inner Whatcom Waterway (Units 2 & 3):** The cleanup of the Inner Whatcom Waterway will be performed using the same approach as with Alternative 4. The alternative assumes that the 1960s federal channel will be updated at the head of the waterway to provide for integrated public access, habitat enhancement and navigation uses. The design concept included in Alternative 5 assumes that the majority of the Inner Whatcom Waterway is managed for effective water depths of between 18 feet and 22 feet. This water depth range provides for navigation opportunities consistent with the mixed-use zoning of the waterfront properties. Under Alternative 5, the emergent tideflats at the head of the waterway are preserved, and shallow-water habitat areas along the sides of the waterway are preserved and enhanced. At the same time, the central portion of the waterway is dredged to depths 5 feet below the planned effective water depth. A sediment cap is then applied over any residual sediments, with the cap grading from a minimum thickness of 3 feet, to a maximum thickness of 6 feet in areas near the Log Pond and Bellingham Shipping Terminal. Shoreline slopes would be stabilized using appropriate side-slopes and materials.

- **Log Pond (Unit 4):** The Log Pond area was previously remediated as part of an Interim Action implemented in 2000. Subsequent monitoring has demonstrated the protectiveness of the subaqueous cap, and the effectiveness of habitat enhancement actions completed as part of that project. Actions in this area will be limited to enhancements to the shoreline edges of the cap, to ensure long-term stability of the cap edges. These enhancements are described in Appendix D of this report.

- **Areas Offshore of ASB (Unit 5):** Exceedances of site-specific cleanup goals within Unit 5-B will be remediated using sub-aqueous capping. Appendix C describes the design concept for this area, including methods to maintain cap stability in a manner compatible with anticipated permitting requirements. The remaining areas of Unit 5 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas at this time. Additional evaluations of sediment stability will be conducted as part of engineering design. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels. Additional measures will be taken in this area only if engineering design evaluations indicate that such measures are required.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The area south of the barge docks at the Bellingham Shipping (Units 6-B and 6-C) contains exceedances of SMS cleanup levels. This area will be remediated using a deep-water sub-aqueous cap. Final water depths in this area will be greater than -18 feet MLLW in most areas, consistent with shoreline infrastructure and navigation uses historically conducted there. The cap will be constructed of coarse granular materials and will be designed to resist potential prop-wash erosion effects. The remaining portions of Unit 6 comply with site-specific cleanup goals. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **Starr Rock (Unit 7):** Sediments in the Starr Rock area currently comply with site-specific cleanup levels. No sediment capping or dredging is proposed for these areas. These areas will be monitored to document the continued effectiveness of natural recovery at complying with cleanup levels.

- **ASB (Unit 8):** Under Alternative 5, the ASB sludges would be removed from the waterfront. The design concept is based on a five-step process. First, the water level in the ASB will be lowered and the connection between the ASB and the outfall plugged. Second, the water treatment equipment (aerators, weirs, etc.) will be removed, and the tops of the berms removed. These berm materials consist of clean sand and stone materials used to construct the ASB and can be reused within other portions of the project area. The exterior of the berm will be reduced in elevation to approximately 16 feet above MLLW. The interior of the berm will be removed to elevations approximately 10 feet above MLLW. Sheet piling will be driven along the berm to prevent migration of impacted water through the berm during dredging. Third, the majority of the ASB sludges will be removed by hydraulic dredging. The hydraulic dredge slurry will be treated in centrifuges or hydrocyclones to separate sludge solids form the entrained waters. Solids separated from the dredge slurry will be shipped by rail for upland disposal. Water from the hydraulic dredging will be returned to the ASB in a closed-loop system, to minimize the overall generation of contaminated waters. The use of hydraulic dredging and maintenance of a water layer overlying the sludges during removal will also minimize odors and potential wildlife exposures during sludge removal. During the fourth step, the impacted waters from the ASB will be pumped out, treated to remove suspended and dissolved contaminants, and will be discharged to the sanitary sewer. If sewer capacity is limited, the treated waters will be managed using a permitted temporary surface water discharge. Finally, the residual solids within the dewatered ASB will be removed by land-based excavation equipment. By conducting this final phase of removal without overlying water, the result will maximize sludge removal and minimize residual contamination. Alternatively, dredge residuals within the ASB could be managed through capping. This would remove the need for dewatering of the ASB, but would limit future depths of ASB reuse. Following cleanout of the sludges, the sheet-piling may be removed from the ASB, the ASB filled to appropriate elevations with surface water, and the berm opened. Some additional impacted sediments will be generated for upland disposal at the time the new access channel to the ASB (Unit 2-B) is created.

6.5.2 Sediment Disposal

Alternative 5 does not involve the creation of new disposal sites within Bellingham Bay. Sediments removed from Waterway under this Alternative will be managed by disposal in appropriately-permitted upland disposal sites. The design concept for Alternative 5 estimates disposal of approximately

76,000 cubic yards of sediments dredged from the Outer and Inner Whatcom Waterway areas and the disposal of approximately 412,000 cubic yards of sludges removed from the ASB. An additional 113,000 cubic yards of sediments dredged from Units 1A and 1B would be managed by beneficial reuse or PSDDA disposal.

The design concept for Alternative 5 assumes that dredged sediments and ASB sludges are shipped by rail to the upland disposal site. Rail shipment is more fuel efficient and provides fewer traffic conflicts than truck transportation. As with Alternative 4, the Alternative 5 design concept and cost estimate assumes the placement of temporary rail improvements at the former GP mill site. Stormwater management and "surge" stockpile areas are included in the project cost assumptions.

6.5.3 Costs & Schedule

The probable costs of Alternative 5 are approximately $42 million (Appendix A). In order of decreasing cost, this estimate addresses removal and disposal of the ASB sludges, dredging and upland disposal of Whatcom Waterway sediments, capping costs for the Waterway and harbor areas, enhancements to the Log Pond shoreline, and provisions for long-term monitoring. Under Alternative 5, clean sediments and stone from the ASB berms are reused within the project as part of capping, shoreline stabilization and habitat enhancement actions.

Because of the work within the ASB, the construction activities are more complex than those in alternative 4, resulting in a longer construction period. The construction of alternative 5 will likely require a three-phase construction cycle, taking place over a 3 to 4 year period. The initial ASB preparation and waterway dredging activities will take place during the first construction phase. The second construction phase will involve ASB sludge removal, dewatering and final ASB cleanout. The final construction phase will involve opening of the ASB berm, completion of final dredging and capping activities within the waterway areas. The first and third phases of construction will be restricted to appropriate "fish windows." The second construction phase will not involve activities in areas connected to surface water, and will not necessarily be subject to "fish window" limitations.

Monitoring of capped and natural recovery areas will occur under Alternative 5. Because natural recovery is only applied in areas that have already achieved compliance with cleanup standards, additional restoration time would not be required.

6.5.4 Changes to Existing Habitat Conditions

Significant changes to existing habitat conditions that will occur as a result of implementing Alternative 5 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 5 includes dredging of the Outer Whatcom Waterway areas. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas in the Outer Whatcom Waterway.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 5, dredging is conducted to support navigation and land uses. This results in some conversion of shallow-water habitat to deep-water habitat. However, the proposed configuration of the multi-purpose channel implemented under Alternative 5 retains existing emergent shallow-water habitat areas at the head and along the sides of the waterway. Under this alternative, waterway shorelines are stabilized with slopes, rather than through the use of bulkheads and hardened shoreline infrastructure. This approach will increase the area and quality of nearshore aquatic habitat. In addition to the habitat effects achieved as a result of Whatcom Waterway cleanup, additional dock and bulkhead removals and shoreline stabilization work is contemplated as part of coordinated cleanup actions at the Central Waterfront site, and as part of mixed-use redevelopment of the properties along the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in changes to substrate type and elevations in shoreline edges of the cap.

- **Areas Offshore of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to likewise enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of “habitat benches” along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. Alternative 5 does not result in any changes to habitat conditions in Units 5A and 5C.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) is to be constructed in deep water and is not expected to significantly modify existing habitat quality. Alternative 5 does not involve any changes to habitat conditions in Unit 6A.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 5 do not modify existing habitat conditions at Starr Rock.

- **ASB (Unit 8):** Alternative 5 includes removal of the ASB sludges and opening of the ASB berm in the Site Unit 2-B. These actions restore the connection of the ASB with Bellingham Bay. This will permit utilization of the interior portions of the ASB by juvenile salmonids and other aquatic organisms. The estimated increase in aquatic area is 28 acres. The estimated length of shoreline migration corridor that would become available for use by juvenile salmonids is just under 4,500 linear feet.

6.5.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 5 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 5 preserves the flexibility for deep draft waterway uses and/or institutional uses at the Bellingham Shipping terminal. The alternative allows for continued maintenance of the federal shipping channel in this area. Some infrastructure maintenance and/or upgrades would likely be required at the shipping terminal to support dredging there.

- **Inner Whatcom Waterway (Units 2 & 3):** As with Alternative 4, Alternative 5 provides for multi-purpose use within the Inner Whatcom Waterway. This multi-purpose use includes public access, habitat enhancement and navigation uses in a manner consistent with the mixed-use zoning. Alternative 5 integrates cleanup actions with that waterfront vision, as in Alternative 4. Infrastructure costs are reduced while simultaneously maximizing land use flexibility and improving both habitat conditions and navigation opportunities.

- **Log Pond (Unit 4):** Consistent with property restrictive covenants, the uses of the Log Pond have been restricted to uses that do not expose capped sediments. This remains unchanged under this alternative and is consistent with planned land uses in nearby areas. Public access (i.e., shoreline promenade) along the Log Pond shoreline is anticipated as part of future area-wide redevelopment activities.

- **Areas Offshore of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the

Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to likewise enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of “habitat benches” along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. The construction of a cap in this area using the proposed design concept does not conflict with current or planned uses of the ASB, or with navigation uses in surrounding areas. Appropriate navigation aids would likely be required in perimeter areas of the cap and habitat bench to prevent inadvertent groundings of small recreational vessels. The water depths in this area are already shallow enough that larger vessels are precluded from this area.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The barge dock area (Unit 6-B & C) will be capped, with a slight reduction in water depth within the capped area.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 5 are consistent with current and anticipated navigation and land uses at Starr Rock.

- **ASB (Unit 8):** The ASB has been identified in previous land use studies as the preferred location for development of a future environmentally sustainable marina with integrated public access and habitat enhancement features (Figure 4-4). Alternative 5 is consistent with such uses.

6.6 Alternative 6

Cleanup Alternative 6 is in most respects the same as Alternative 5. The difference between the alternatives, is that under Alternative 6 additional dredging is conducted adjacent to the Bellingham Shipping Terminal. Other features of the Alternative, including the cleanout of the ASB and the remedial approach to the Inner Whatcom Waterway and Harbor areas are the same as in Alternative 5. Alternative 6 is shown in Figure 6-6.

6.6.1 Actions by Site Unit

A detailed description of Alternative 6 follows. Because many aspects of this alternative are the same as with Alternative 5, the alternative description focuses only on areas of difference between the two cleanup alternatives. Both conduct remediation of the ASB using removal, treatment and upland disposal technologies. They both remediate the Inner Whatcom Waterway with dredging and capping, consistent with the vision of a locally-managed multi-purpose channel. Remediation activities outside of the waterway are also similar, including development of a cap and habitat bench along the ASB shoulder (Unit 5-B) and capping in the barge dock area (Unit 6B and 6C). The principal difference between the two alternatives is the extent of dredging near the Bellingham Shipping Terminal (Unit 1-C).

Under Alternative 5, the extent of dredging provides for maintenance of the 30-ft federal channel. This requires dredging to depths of at least 35 feet below MLLW. Residual sediments are capped with a thick layer of sediment. In contrast, Alternative 6 conducts sediment removal in the Unit 1-C area to the extent technically practicable. Under this alternative, the depth of dredge cuts would be increased, in most areas extending dredging to the interface with clean native sediments. The depth of dredging under Alternative 6 would range from 35 feet to 41 feet below MLLW in Unit 1-C. The dredging would need to address geotechnical and structural integrity limitations associated with existing piers and structures in the terminal area. However, it is expected that most portions of Unit 1C could be remediated, without requiring subsequent application of a thick cap.

6.6.2 Sediment Disposal

As with Alternative 5, all impacted sediments dredged from the Waterway and all of the sludges removed from the ASB would be managed by upland disposal at appropriately permitted facilities. Alternative 6 does not involve the creation of new disposal sites within Bellingham Bay.

The design concept for Alternative 6 estimates disposal of approximately 118,000 cubic yards of sediments dredged from the Outer and Inner Whatcom Waterway areas and the disposal of approximately 412,000 cubic yards of sludges removed from the ASB. An additional 113,000 cubic yards of sediments dredged from Units 1A and 1B would be managed by beneficial reuse or PSDDA disposal.

Transportation of sediments for upland disposal would be conducted by rail to minimize fuel use and avoid potential traffic impacts. The design concept and cost estimate assumes the placement of supplemental temporary rail improvements at the former GP mill site. Stormwater management and "surge" stockpile areas are included in the project cost assumptions.

6.6.3 Costs & Schedule

The probable costs of Alternative 6 are approximately $44 million. In order of decreasing cost, this estimate addresses removal and disposal of the ASB sludges, dredging and upland disposal of Whatcom Waterway sediments, capping costs for the portions of the Waterway and harbor areas, enhancements to the Log Pond shoreline, and provisions for long-term monitoring (Appendices A and B). Under Alternative 6, clean sediments and stone from the ASB berms are reused within the project as part of capping, shoreline stabilization and habitat enhancement actions.

The schedule and phasing of construction activities under Alternative 6 are similar to those under Alternative 5. The work will likely require a three-phase construction cycle, taking place over a 3 to 4 year period. The initial ASB preparation and waterway dredging activities will take place during the first construction phase. The second construction phase will involve ASB sludge removal, dewatering and final cleanout. The final construction phase will involve opening of the ASB berm, completion of final dredging and capping activities within the waterway areas. The first and third phases of construction will be restricted to appropriate “fish windows.” The second construction phase will not involve activities in areas connected to surface water, and will not necessarily be subject to “fish window” limitations.

Monitoring of capped and natural recovery areas will occur under Alternative 6. Because natural recovery is only applied in areas that have already achieved compliance with cleanup standards, additional restoration time would not be required.

6.6.4 Changes to Existing Habitat Conditions

Table 6-2 summarizes the changes to existing habitat conditions that are associated with the implementation of Alternative 6. Most habitat changes associated with Alternative 6 are the same as those for Alternative 5.

Alternative 6 involves additional dredging within Unit 1C. However, this dredging takes place in deep water, with no significant changes to shallow-water habitat areas. The dredging would not significantly affect (positively or negatively) aquatic habitat functions or values in this area.

6.6.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 6 are summarized in Table 6-2. These land use and navigation issues are virtually identical to those of alternative 5.

The only difference in land use benefits between Alternative 5 and Alternative 6 is the flexibility provided by Alternative 6 for future depth changes in the deep draft portions of the Whatcom Waterway (Unit 1-C). By removing sediments to the limits of technical and economic practicability, Alternative 6 provides for additional navigation flexibility at the Bellingham Shipping Terminal. Potentially the navigation depth of the federal channel near the terminal could be increased at a future date, should such an increase be warranted. This additional flexibility is obtained at an incremental cost of approximately $3 million, in comparison to Alternative 5.

6.7 Alternative 7

Alternative 7 uses the same technologies as Alternatives 5 and 6 to comply with SMS cleanup levels. These include institutional controls, monitored natural recovery, containment, removal & disposal, treatment and reuse & recycling. Alternative 7 is shown in Figure 6-7.

The elements of Alternative 7 and the differences between it and alternatives 5 and 6 are described below by site Unit.

6.7.1 Actions by Site Unit

Like Alternative 5 and 6, Alternative 7 uses hybrid technologies to accomplish the remediation of the Whatcom Waterway site. The ASB is remediated using removal, treatment and upland disposal technologies, consistent with alternatives 5 and 6. The Outer Whatcom Waterway areas are similarly remediated by dredging and upland disposal, as in Alternative 6. Unlike the preceding Alternatives, Alternative 7 removes sediment from the Inner Whatcom Waterway to allow use and maintenance of the 1960's federal channel.

Under Alternative 7 dredging is conducted consistent with the dredge prisms used in Alternative 2 and Alternative 3. Impacted sediments that are more than 5 feet below the 1960s channel project depth are capped in place, using a thick sediment cap. Capping may also be used in nearshore berth areas where full sediment removal is technically impracticable, or where the shoreline infrastructure does not allow sediments to be removed without compromising side-slope stability or the integrity of existing structures.

Other aspects of Alternative 7 remain the same as in alternative 6. These include the capping of the ASB shoulder and barge dock area, the enhancements to the Log Pond shoreline, and the use of monitored natural recovery for other bottom areas that currently comply with site cleanup levels.

6.7.2 Sediment Disposal

Alternative 7 does not involve the creation of new disposal sites within Bellingham Bay. Sediments removed from the Waterway under this Alternative will be managed by disposal in appropriately-permitted upland disposal sites. The design concept for Alternative 7 estimates disposal of approximately 479,000 cubic yards of sediments dredged from the Outer and Inner Whatcom Waterway areas and the disposal of approximately 412,000 cubic yards of sludges removed from the ASB. This represents an increase of 113,000 cubic yards of sediment disposal over that provided in Alternative 6. This additional volume substantially increases project remedial costs, without a corresponding increase in remedy protectiveness.

As with Alternative 6, the design concept for Alternative 7 assumes that dredged sediments and ASB sludges are shipped by rail to the upland disposal site. Rail shipment is more fuel efficient and provides fewer traffic conflicts than truck transportation.

6.7.3 Costs & Schedule

The probable costs of Alternative 7 are $74 million (Appendix A). In order of decreasing cost, this estimate addresses dredging and upland disposal of the 1960s federal channel sediments, removal and disposal of the ASB sludges, capping costs for the portions of the Waterway and harbor areas, enhancements to the Log Pond shoreline, and provisions for long-term monitoring. This cost is nearly double that of Alternative 6, while providing only a slight increase in overall remedy protectiveness. The remedy provides a lower habitat benefit than in Alternative 6, and is not consistent with community land use objectives as described below.

Like Alternatives 2 and 3, implementation of Alternative 7 must be integrated with shoreline infrastructure upgrades along the Inner Whatcom Waterway shoreline. This will increase the time required for project design and permitting relative to Alternative 6. The additional dredging involved in Alternative 7 also increases the duration and complexity of project construction activities. Alternative 7 is likely to require an additional year of construction over that required in Alternative 6.

Monitoring of capped and natural recovery areas will occur under Alternative 7. Because natural recovery is only applied in areas that have already achieved compliance with cleanup standards, additional restoration time would not be required for natural recovery to occur.

6.7.4 Changes to Existing Habitat Conditions

Significant changes to existing habitat conditions that will occur as a result of implementing Alternative 7 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 7 includes dredging of the Outer Whatcom Waterway areas. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 7, dredging of the Inner Whatcom Waterway is conducted consistent with the boundaries of the 1960s federal channel. This requires the removal of emergent shallow-water habitat at the head and along the sides of the channel. Further, to achieve target dredge depths and navigation conditions, the shorelines must be hardened with bulkheads and other infrastructure similar to that shown in Figure 4-2. The application of this shoreline infrastructure would further reduce the existing quality of nearshore aquatic habitat within the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in changes to substrate type and elevations in shoreline edges of the cap.

- **Areas Offshore of ASB (Unit 5):** The design concept for the sediment cap at the shoulder of the ASB (Unit 5-B; design concept included in Appendix C) results in an increase in sediment elevation from between -6 to -10 feet MLLW to elevations between -3 to -6 feet MLLW. The measures applied in the Appendix C design concept to reduce wave energy and stabilize the cap surface are expected to likewise enhance habitat quality by facilitating the growth of aquatic vegetation. These changes are consistent with previous the Bellingham Bay Comprehensive Strategy which identifies the development of “habitat benches” along this portion of the shoreline to enhance habitat quality for migrating juvenile salmonids. Alternative 7 does not result in any changes to habitat conditions in Units 5A and 5C.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** The cap in the barge dock area (Unit 6-B & C) is to be constructed in deep water and is not expected to significantly modify existing habitat quality. Alternative 7 does not involve any changes to habitat conditions in Unit 6A.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 7 do not modify existing habitat conditions at Starr Rock.

- **ASB (Unit 8):** Alternative 7 includes removal of the ASB sludges and opening of the ASB berm in the Site Unit 2-B. These actions restore the connection of the ASB with Bellingham Bay. This will permit utilization of the interior portions of the ASB by juvenile salmonids and other aquatic organisms. The estimated increase in aquatic area is 28 acres. The estimated length of shoreline migration corridor that would become available for use by juvenile salmonids is just under 4,500 linear feet.

6.7.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 7 are summarized in Table 6-2. For the ASB, Outer Whatcom Waterway and most other site areas, the land use benefits and impacts of Alternative 7 are identical to those of Alternatives 5 and 6. The principal difference for Alternative 7 is the treatment of the Inner Whatcom Waterway.

As with Alternatives 2 and 3, Alternative 7 conducts dredging of the Inner Whatcom Waterway based on the obsolete 1960s federal channel dimensions.

That channel was established for an industrial land use pattern that is inconsistent with current zoning and redevelopment planning. Further, the infrastructure required to fully implement the 1960s federal channel was never fully developed, resulting in shorelines in most of the Inner Whatcom Waterway area that are incapable of achieving an effective water depth consistent with the 1960s channel dimensions. These shorelines were constructed earlier based on the historical 18-foot waterway depth. If Alternative 7 is implemented, then it will trigger extensive infrastructure requirements along much of the Inner Whatcom Waterway.

Community land use planning efforts have emphasized the need to provide for multiple waterfront uses in the Inner Whatcom Waterway area. These uses include shoreline public access, habitat enhancement and navigation uses in a manner consistent with the mixed-use waterfront zoning. Alternative 7 conflicts with planned land and navigation uses in the Inner Whatcom Waterway. In order to support deep draft dredging in this area, substantial shoreline infrastructure upgrades are required. These upgrades are inconsistent with habitat enhancement actions in these same areas. Secondly, the land uses necessary to justify Corps participation in future channel maintenance likely conflict with mixed-use redevelopment and shoreline public access objectives. Some navigation uses such as transient moorage may be precluded, or may be significantly restricted in the Inner Whatcom Waterway areas. This contrasts with other FS Alternatives (i.e., Alternatives 4, 5 and 6) that assume the application of a mixed-use channel within the Inner Whatcom Waterway.

The alternative approach to implementing Alternative 7 would be to dredge only the federal channel areas that can be dredged while leaving geotechnically stable side-slopes. This would avoid direct triggering of additional infrastructure requirements, but would limit waterway navigation uses unless the waterway was reauthorized consistent with Alternatives 4, 5 and 6.

In summary, Alternative 7 does not provide incremental benefits to area land uses. Rather, the alternative is based on an obsolete industrial waterway vision that was never fully implemented and that never received the requisite investments in shoreline infrastructure upgrades. The alternative does not enhance navigation opportunities within the Whatcom Waterway, since a full range of intermediate to deep draft uses is already provided under Alternatives 5 and 6. Implementation of Alternative 7 would adversely impact area land use and redevelopment potential by creating additional cost burdens on property owners and local governments (i.e., requirements to upgrade shoreline infrastructure), and by restricting shoreline land use flexibility as necessary to maintain a federal interest in navigation channel maintenance. These issues are significant in the comparative evaluation of alternatives conducted in Section 6.

6.8 Alternative 8

Alternative 8 is the last of the alternatives evaluated in the Feasibility Study. The Alternative uses the same range of technologies evaluated for Alternatives 5, 6 and 7 to comply with SMS cleanup levels. However, the extent of dredging and upland disposal is expanded under Alternative 8 relative to the preceding alternatives. Alternative 8 is shown in Figure 6-8

6.8.1 Actions by Site Unit

Alternative 8 manages most site cleanup areas through sediment removal and upland disposal. Like preceding alternatives, Alternative 8 conducts removal and upland disposal for the sludges within the ASB and for sediments within the Waterway navigation areas. However, Alternative 8 also removes sediments in outlying portions of the site, including areas addressed by capping and monitored natural recovery under other alternatives.

- **Outer Whatcom Waterway (Unit 1):** Dredging of the Outer Whatcom Waterway is conducted the same as for Alternatives 6 and 7. Dredging is conducted to native bottom sediments except where this is not technically feasible. Sediments are managed by upland disposal, except for those sediments of Unit 1A and 1B that may be suitable for beneficial reuse or PSDDA disposal.

- **Inner Whatcom Waterway (Units 2 & 3):** Like Alternatives 2, 3 and 7, this alternative conducts dredging within the Inner Whatcom Waterway as necessary to provide for future use and maintenance of the federal navigation channel to the head of the waterway. The 1960s federal channel boundaries specify a water depth of 30 feet below MLLW from the BST area to Maple Street. A depth of 18 feet is specified from Maple Street to the head of the waterway. In the deeper portion of the waterway, the dredging cut would be established at depths at least 35 feet below MLLW. This would remove sediments where technically feasible, and would provide sufficient over-depth to allow residual sediments to be capped without impeding future maintenance of the federal channel. The design concept assumes a cap thickness of 3 feet over dredged areas with residual subsurface sediment impacts. Due to historical encroachment of the shoreline on the federal channel boundaries, many of the Inner Whatcom Waterway shoreline areas have fill and bulkheads up to or near to the pierhead line. Most of these bulkheads would require replacement and/or substantial upgrades in order to maintain shoreline stability in these areas during and after dredging. Docks may also have to be upgraded or replaced as described in Alternative 2 in order to accommodate federal channel dredging and future use. Containment by capping with appropriate institutional controls will be required for areas where removal is not technically feasible.

- **Log Pond (Unit 4):** The Log Pond area was previously remediated as part of an Interim Action implemented in 2000. Subsequent monitoring has demonstrated the protectiveness of the subaqueous cap, and the effectiveness of habitat enhancement actions completed as part of that project. Actions in this area will be limited to enhancements to the shoreline edges of the cap, to ensure long-term stability of the cap edges. These enhancements are described in Appendix D of this report.

- **Areas offshore of ASB, Areas Near Bellingham Shipping Terminal, Starr Rock (Units 5, 6 & 7):** Under Alternative 8 dredging with upland disposal will be implemented in Unit 5 (ASB shoulder area), Unit 6 (Areas Near Bellingham Shipping Terminals) and Unit 7 (Starr Rock area). Sediments that currently exceed cleanup standards, as well as those that currently comply with cleanup standards would be removed. As with portions of the Inner Whatcom Waterway, some residual sediments would remain in areas where removal was not technically feasible. Some institutional controls, monitoring and/or containment would likely be required in portions of the harbor and bottom areas.

- **ASB (Unit 8):** As with Alternatives 5, 6 and 7, the ASB sludges are removed, treated to reduce volume and are disposed at a permitted upland disposal facility. Removal methods are the same as in the preceding alternatives.

6.8.2 Sediment Disposal

Alternative 8 does not involve the creation of new disposal sites within Bellingham Bay. Sediments removed from Waterway under this Alternative will be managed by disposal in appropriately-permitted upland disposal sites. The design concept for Alternative 8 estimates disposal of approximately 1.26 million cubic yards of dredged sediments and the disposal of approximately 412,000 cubic yards of sludges removed from the ASB. This is a dramatic increase in the disposal volumes over the preceding alternatives.

6.8.3 Costs & Schedule

The probable costs of Alternative 8 are approximately $146 million (Appendices A and B). This cost is nearly double that of Alternative 7, and is over three times higher than the cost of Alternatives 5 and 6.

The implementation of Alternative 8 will require extensive design and permitting prior to initiation of construction. In areas of the Inner Whatcom Waterway, project planning must be coordinated with future shoreline infrastructure improvements. A design and permitting period of 3 to 6 years is estimated.

The additional dredging involved in Alternative 8 will result in a substantial increase to the duration of project construction. All of the additional dredging will involve work in restricted “fish windows.” The project is expected to require between 5 and 7 construction seasons, with in-water work activities during each of those seasons. Including project design and permitting, the restoration time for Alternative 8 is estimated at 8 to 13 years.

Monitoring will likely be required in some areas where removal of sediments is not technically feasible and the application of capping and/or natural recovery is required. As with preceding alternatives, capping is assumed for these areas, resulting in no additional restoration time to achieve compliance with cleanup levels in these areas.

6.8.4 Changes to Existing Habitat Conditions

Significant changes to existing habitat conditions that will occur as a result of implementing Alternative 8 are summarized in Table 6-2 and include the following:

- **Outer Whatcom Waterway (Unit 1):** Alternative 8 includes dredging of the Outer Whatcom Waterway areas. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas.

- **Inner Whatcom Waterway (Units 2 & 3):** Under Alternative 8, dredging of the Inner Whatcom Waterway is conducted consistent with the boundaries of the 1960s federal channel. This requires the removal of emergent shallow-water habitat at the head and along the sides of the channel. Further, to achieve target dredge depths and navigation conditions, the shorelines must be hardened with bulkheads and other infrastructure similar to that shown in Figure 4-2. The application of this shoreline infrastructure would further reduce the existing quality of nearshore aquatic habitat within the Inner Whatcom Waterway.

- **Log Pond (Unit 4):** Construction of shoreline enhancements consistent with the design concept in Appendix D will result in changes to substrate type and elevations in shoreline edges of the cap.

- **Areas offshore of ASB, Areas Near Bellingham Shipping Terminal, Starr Rock (Units 5, 6, & 7):** The dredging of the harbor areas would not produce the habitat bench near the shoulder of the ASB provided under the other alternatives. Rather, the dredging would reduce mud-line elevations in this area and result in a net reduction in habitat quality in this area. This type of habitat conversion is inconsistent with habitat preservation and enhancement goals of the Bellingham Bay Comprehensive Strategy.

- **Areas Offshore of ASB (Unit 5):** Under Alternative 8, remediation of Unit 5 sediments is conducted by dredging. Portions of Unit 5 are located in shallow-water areas. Dredging in these areas will result in conversions from shallow-water to deeper-water habitat. These conversions would reduce the quality of this area for use by juvenile salmonids.

- **Areas Near Bellingham Shipping Terminal (Unit 6):** Under Alternative 8, remediation of Unit 6 sediments is conducted by dredging. However, Unit 6 consists primarily of deep-water areas. Therefore, dredging of Unit 6 is not expected to result in changes to existing habitat that might adversely impact use by juvenile salmonids.

- **Starr Rock (Unit 7):** Cleanup activities under Alternative 8 will include dredging at Starr Rock. However, this dredging occurs in deep water and does not significantly affect shallow-water habitat areas.

- **ASB (Unit 8):** Alternative 8 includes removal of the ASB sludges and opening of the ASB berm in the Site Unit 2-B. These actions restore the connection of the ASB with Bellingham Bay. This will permit utilization of the interior portions of the ASB by juvenile salmonids and other aquatic organisms. The estimated increase in aquatic area is 28 acres. The estimated length of shoreline migration corridor that would become available for use by juvenile salmonids is just under 4,500 linear feet.

6.8.5 Land Use & Navigation Considerations

Significant land use and navigation considerations associated with the implementation of Alternative 8 are summarized in Table 6-2. These land use and navigation issues are generally the same as for Alternative 7. The additional dredging in the harbor and bottom areas of the Bay provides no incremental benefit to area navigation. As with Alternative 7, the dredging approach to the Inner Whatcom Waterway under Alternative 8 is inconsistent with current area zoning, and planned mixed-use redevelopment of the Inner Whatcom Waterway areas.

Some temporary disruption to area land uses will be encountered during implementation of the cleanup action, due to the extended duration of project construction activities.

Table 6-2. Detailed Description of Site Remediation Alternatives

Alternative Name & Description		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Design Concept Figure		Figure 6-1	Figure 6-2	Figure 6-3	Figure 6-4	Figure 6-5	Figure 6-6	Figure 6-7	Figure 6-8
Probable Cost ($ million)		$8 million	$34 million	$34 million	$21 million	$42 million	$44 million	$74 million	$146 million
Est. Time for Design/Construction (yrs)		6 to 12 yrs	6 to 9 yrs	5 to 8 yrs	3 to 4 yrs	5 to 6 yrs	5 to 6 yrs	7 to 9 yrs	8 to 13 yrs
ASB Area Summary [1]		Capping of ASB Sludges	Capping of ASB Sludges	Containment of ASB Sludges within Nearshore Fill	Capping of ASB Sludges	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]
Waterway Area Summary [1]		Capping and Monitored Natural Recovery with Restricted Channel Depths [2]	Dredging of 1960s Federal Channel with Disposal at Cornwall Confined Aquatic Disposal (CAD)	Dredging of 1960s Federal Channel with Disposal in ASB Nearshore Fill	Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Expanded Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of 1960s Federal Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of 1960s Federal Channel & Additional Areas with Upland Disposal in Subtitle D Facility [5]
1. Cleanup Actions by Site Unit									
Outer Whatcom Waterway	Site Unit								
Outer Channel	Units 1A/1B	Monitored Natural Recovery & Institutional Controls	Dredging with Placement in Cornwall-Area CAD Site	Dredging with Placement in ASB Nearshore Fill	Dredging with Beneficial Reuse or PSDDA Disposal	Dredging with Beneficial Reuse or PSDDA Disposal	Dredging with Beneficial Reuse or PSDDA Disposal	Dredging with Beneficial Reuse or PSDDA Disposal	Dredging with Beneficial Reuse or PSDDA Disposal
Port Terminal Area	Unit 1C	Monitored Natural Recovery & Institutional Controls	Expanded Dredging[8] with Placement in Cornwall-Area CAD	Expanded Dredging[8] with Placement in ASB Nearshore Fill	Dredging for 30-ft Deep Draft Uses with Subtitle D Disposal, Followed by Capping & Institutional Controls	Dredging for 30-ft Deep Draft Uses with Subtitle D Disposal, Followed by Capping & Institutional Controls	Expanded Dredging[8] with Subtitle D Sediment Disposal	Expanded Dredging[8] with Subtitle D Sediment Disposal	Expanded Dredging[8] with Subtitle D Sediment Disposal
Inner Whatcom Waterway									
Inner Waterway	Unit 2A, 2C & 3B	Monitored Natural Recovery & Institutional Controls	Dredging of 1960s Federal Channel with Placement in Cornwall-Area CAD Site, Followed by Capping & Institutional Controls	Dredging of 1960s Federal Channel with Placement in ASB Nearshore Fill, Followed by Capping & Institutional Controls	Dredging for Multi-Purpose Channel with Subtitle D Disposal, Followed by Capping & Institutional Controls	Dredging for Multi-Purpose Channel with Subtitle D Disposal, Followed by Capping & Institutional Controls	Dredging for Multi-Purpose Channel with Subtitle D Disposal, Followed by Capping & Institutional Controls	Dredging of 1960s Federal Channel with Subtitle D Disposal, Followed by Capping & Institutional Controls	Dredging of 1960s Federal Channel with Subtitle D Disposal, Followed by Capping & Institutional Controls
ASB Access Channel	Unit 2B	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Dredging for 18-ft Access Channel with Subtitle D Disposal	Dredging for 18-ft Access Channel with Subtitle D Disposal	Dredging for 18-ft Access Channel with Subtitle D Disposal	Dredging & Subtitle D Disposal
Emergent Tideflat	Units 3A	Monitored Natural Recovery & Institutional Controls	Dredging of 1960s Industrial Channel with Disposal in Cornwall-Area CAD Site	Dredging of 1960s Industrial Channel with Disposal in ASB Nearshore Fill	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Dredging of 1960s Federal Channel with Subtitle D Disposal	Dredging of 1960s Federal Channel with Subtitle D Disposal
Log Pond	Unit 4	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]	Enhancements to Shoreline Cap Edges [6]
Areas Offshore of ASB									
Offshore of ASB	Unit 5A	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Dredging & Subtitle D Disposal
Shoulder of ASB	Unit 5B	Sediment Capping[7] & Institutional Controls	Sediment Capping[7] & Institutional Controls	Sediment Capping[7] & Institutional Controls	Sediment Capping[7] & Institutional Controls	Sediment Capping[7] & Institutional Controls	Sediment Capping[7] & Institutional Controls	Sediment Capping[7] & Institutional Controls	Dredging & Subtitle D Disposal
Waterway Side of ASB	Unit 5C	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Dredging & Subtitle D Disposal
Areas Near Bellingham Shipping Terminal									
Recovered Harbor Areas	Unit 6A	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Dredging & Subtitle D Disposal
Barge Dock Area	Unit 6B, 6C	Sediment Capping & Insitutional Controls	Sediment Capping & Insitutional Controls	Sediment Capping & Insitutional Controls	Sediment Capping & Insitutional Controls	Sediment Capping & Insitutional Controls	Sediment Capping & Insitutional Controls	Sediment Capping & Insitutional Controls	Dredging & Subtitle D Disposal
Starr Rock	Unit 7	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Monitored Natural Recovery & Institutional Controls	Dredging & Subtitle D Disposal
ASB	Unit 8	Capping of ASB Sludges	Capping of ASB Sludges	Containment of ASB Sludges within Nearshore Fill	Capping of ASB Sludges	Removal of ASB sludges with Dewatering & Subtitle D Disposal	Removal of ASB sludges with Dewatering & Subtitle D Disposal	Removal of ASB sludges with Dewatering & Subtitle D Disposal	Removal of ASB sludges with Dewatering & Subtitle D Disposal
2. Sediment Disposal									
ASB Sludges	Unit 8	-- NA[3] --	-- NA[3] --	-- NA[3] --	-- NA[3] --	Removal, Dewatering & Subtitle D Disposal of 412,000 cyd ASB Sludges and Overdredge	Removal, Dewatering & Subtitle D Disposal of 412,000 cyd ASB Sludges and Overdredge	Removal, Dewatering & Subtitle D Disposal of 412,000 cyd ASB Sludges and Overdredge	Removal, Dewatering & Subtitle D Disposal of 412,000 cyd ASB Sludges and Overdredge
Aquatic Sediments	All Other Areas	-- NA[4] --	Containment of 585,000 cyd sediments in Cornwall CAD	Containment of 585,000 cyd sediments in ASB Nearshore Fill	Dredging & Subtitle D Disposal of 68,000 cyd Sediments	Dredging & Subtitle D Disposal of 76,000 cyd Sediments	Dredging & Subtitle D Disposal of 118,000 cyd Sediments	Dredging & Subtitle D Disposal of 479,000 cyd Sediments	Dredging & Subtitle D Disposal of 1.26 million cyd Sediments
					Beneficial Use or PSDDA Disposal of 113,000 cyd Unit 1A/1B Sediment	Beneficial Use or PSDDA Disposal of 113,000 cyd Unit 1A/1B Sediment	Beneficial Use or PSDDA Disposal of 113,000 cyd Unit 1A/1B Sediment	Beneficial Use or PSDDA Disposal of 113,000 cyd Unit 1A/1B Sediment	Beneficial Use or PSDDA Disposal of 113,000 cyd Unit 1A/1B Sediment

Notes:

1: All remedial alternatives involve the use of institutional controls, containment and monitoring to varying degrees. Refer to Sections 1 through 4 of this table for a specific description of remedial alternatives by Sediment Site Unit.
2: Channel depths will be restricted to depths shallower than current bathymetry under Alternative 1, as no dredging would be conducted either in the Inner Waterway or Outer Waterway areas.
3. Not applicable. Under this alternative, no removal of the ASB sludges will be conducted.
4. Not applicable. Under this alternative, no waterway sediment dredging will be conducted.
5. A Subtitle D Facility is a landfill that is designed and permitted for management of solid waste, and includes a liner, a cap, a monitoring network, and institutional controls and financial assurance provisions under state and federal solid waste regulations.
6. The design concept for stabilizing the shoreline cap edges is illustrated in Appendix D. The Log Pond area is subject to institutional controls recorded as part of the Log Pond Interim Remedial Action.
7. The design concept for the cap in the Unit 5B area is illustrated in Appendix C.
8. Dredging in this area will be conducted to the base of the contaminated sediments, and requirements for capping of the dredged area are not anticipated.

Table 6-2. Detailed Description of Site Remediation Alternatives

Alternative Name & Description		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
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Probable Cost ($ million)		$8 million	$34 million	$34 million	$21 million	$42 million	$44 million	$74 million	$146 million
Est. Time for Design/Construction (yrs)		6 to 12 yrs	6 to 9 yrs	5 to 8 yrs	3 to 4 yrs	5 to 6 yrs	5 to 6 yrs	7 to 9 yrs	8 to 13 yrs
ASB Area Summary [1]		Capping of ASB Sludges	Capping of ASB Sludges	Containment of ASB Sludges within Nearshore Fill	Capping of ASB Sludges	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]
Waterway Area Summary [1]		Capping and Monitored Natural Recovery with Restricted Channel Depths [2]	Dredging of 1960s Federal Channel with Disposal at Cornwall Confined Aquatic Disposal (CAD)	Dredging of 1960s Federal Channel with Disposal in ASB Nearshore Fill	Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Expanded Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of 1960s Federal Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of 1960s Federal Channel & Additional Areas with Upland Disposal in Subtitle D Facility [5]
3. Changes to Existing Habitat Conditions									
Outer Whatcom Waterway	Units 1A, 1B & 1C	No Change	No Significant Changes -- Dredging Occurs in Deep-Water Areas	No Significant Changes -- Dredging Occurs in Deep-Water Areas	No Significant Changes -- Dredging Occurs in Deep-Water Areas	No Significant Changes -- Dredging Occurs in Deep-Water Areas	No Significant Changes -- Dredging Occurs in Deep-Water Areas	No Significant Changes -- Dredging Occurs in Deep-Water Areas	No Significant Changes -- Dredging Occurs in Deep-Water Areas
Inner Whatcom Waterway									
Inner Waterway	Unit 2A, 2C & 3B	Absence of Deep Dredging Retains Shallow-Water Habitat in Nearshore Shoaled Areas	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat and Requires Continued Use of Hardened Shorelines and Bulkheads to Achieve Target Dredge Depths	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat and Requires Continued Use of Hardened Shorelines and Bulkheads to Achieve Target Dredge Depths	Use of Sloping Shoreline Stabilization Methods Consistent with Multi-Purpose Channel Dimensions Preserves and Enhances Shallow-Water Habitat Along Salmonid Migration Corridors	Use of Sloping Shoreline Stabilization Methods Consistent with Multi-Purpose Channel Dimensions Preserves and Enhances Shallow-Water Habitat Along Salmonid Migration Corridors	Use of Sloping Shoreline Stabilization Methods Consistent with Multi-Purpose Channel Dimensions Preserves and Enhances Shallow-Water Habitat Along Salmonid Migration Corridors	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat and Requires Continued Use of Hardened Shorelines and Bulkheads to Achieve Target Dredge Depths	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat and Requires Continued Use of Hardened Shorelines and Bulkheads to Achieve Target Dredge Depths
ASB Access Channel	Unit 2B	No Change to Existing Shallow-Water Area	No Change to Existing Shallow-Water Area	No Change to Existing Shallow-Water Area	No Change to Existing Shallow-Water Area	Dredging of Channel Converts 0.7 Acres of Shallow-Water Habitat to Deep-Water Bottom Areas	Dredging of Channel Converts 0.7 Acres of Shallow-Water Habitat to Deep-Water Bottom Areas	Dredging of Channel Converts 0.7 Acres of Shallow-Water Habitat to Deep-Water Bottom Areas	Dredging of Channel Converts 0.7 Acres of Shallow-Water Habitat to Deep-Water Bottom Areas
Emergent Tideflat	Units 3A	No Change -- Emergent Shallow-Water Habitat is Preserved	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat	No Change -- Multi-Purpose Channel Preserves Emergent Shallow-Water Habitat	No Change -- Multi-Purpose Channel Preserves Emergent Shallow-Water Habitat	No Change -- Multi-Purpose Channel Preserves Emergent Shallow-Water Habitat	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat	Dredging of 1960s Industrial Channel Removes Emergent Shallow-Water Habitat
Log Pond	Unit 4	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond	Substrate Modifications Required to Stabilize Shoreline Edges of Log Pond
Areas Offshore of ASB									
Shoulder of ASB	Unit 5B	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Capping Design Concept Creates 4 to 6 Acres of Premium Nearshore Habitat	Dredging Converts 4 to 6 Acres of Shallow-Water Area to Deep-Water Area
Other Unit 5 Areas	Units 5A & 5C	No Change	No Change	No Change	No Change	No Change	No Change	No Change	Dredging Results in Deepening of Existing Shallow-Water Habitat Areas Along ASB Berm
Areas Near Bellingham Shipping Terminal									
Barge Dock Area	Unit 6B, 6C	No Change -- Capping Limited to Deep-Water Areas	No Change -- Capping Limited to Deep-Water Areas	No Change -- Capping Limited to Deep-Water Areas	No Change -- Capping Limited to Deep-Water Areas	No Change -- Capping Limited to Deep-Water Areas	No Change -- Capping Limited to Deep-Water Areas	No Change -- Capping Limited to Deep-Water Areas	No Change -- Dredging Limited to Deep-Water Areas
Other Unit 6 Areas	Unit 6A	No Change	No Change	No Change	No Change	No Change	No Change	No Change	Dredging will Result in Deepening of Shallow-Water Nearshore Habitat Areas
Starr Rock	Unit 7	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change -- Dredging Limited to Deep-Water Areas
ASB	Unit 8	No Change -- ASB Sludges are Capped and Area Remains Isolated from Bellingham Bay	No Change -- ASB Sludges are Capped and Area Remains Isolated from Bellingham Bay	Nearshore Fill is Constructed within ASB, Converting Area Permanently to Upland Characteristics	No Change -- ASB Sludges are Capped and Area Remains Isolated from Bellingham Bay	ASB Sludges are Removed and Berm is Opened, Restoring Connection of ASB Basin with Bellingham Bay	ASB Sludges are Removed and Berm is Opened, Restoring Connection of ASB Basin with Bellingham Bay	ASB Sludges are Removed and Berm is Opened, Restoring Connection of ASB Basin with Bellingham Bay	ASB Sludges are Removed and Berm is Opened, Restoring Connection of ASB Basin with Bellingham Bay

Table 6-2. Detailed Description of Site Remediation Alternatives

Alternative Name & Description		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Design Concept Figure		Figure 6-1	Figure 6-2	Figure 6-3	Figure 6-4	Figure 6-5	Figure 6-6	Figure 6-7	Figure 6-8
Probable Cost ($ million)		$8 million	$34 million	$34 million	$21 million	$42 million	$44 million	$74 million	$146 million
Est. Time for Design/Construction (yrs)		6 to 12 yrs	6 to 9 yrs	5 to 8 yrs	3 to 4 yrs	5 to 6 yrs	5 to 6 yrs	7 to 9 yrs	8 to 13 yrs
ASB Area Summary [1]		Capping of ASB Sludges	Capping of ASB Sludges	Containment of ASB Sludges within Nearshore Fill	Capping of ASB Sludges	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]	Removal, Treatment & Disposal of ASB Sludge in Subtitle D Facility [5]
Waterway Area Summary [1]		Capping and Monitored Natural Recovery with Restricted Channel Depths [2]	Dredging of 1960s Federal Channel with Disposal at Cornwall Confined Aquatic Disposal (CAD)	Dredging of 1960s Federal Channel with Disposal in ASB Nearshore Fill	Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Expanded Dredging of Multi-Purpose Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of 1960s Federal Channel with Upland Disposal in Subtitle D Facility [5]	Dredging of 1960s Federal Channel & Additional Areas with Upland Disposal in Subtitle D Facility [5]
4. Land Use & Navigation Considerations									
Outer Whatcom Waterway	Units 1A, 1B & 1C	Restricted Water Depths will Limit Future Deep-Draft Uses of Terminal Area, Conflicting with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses	Dredging in Outer Waterway Preserves Deep Draft Uses of Terminal Area, Consistent with Current and Planned Uses
Inner Whatcom Waterway									
Inner Waterway	Unit 2A, 2C & 3B	Restricted Water Depths and Lack of Stabilized Shorelines will Limit Future Inner Waterway Navigation & Land Uses.	Industrial Shoreline Infrastructure Requirements and Land Use Restrictions Associated with Federal Channel Conflict with Planned Mixed-Use Redevelopment & Habitat Enhancements.	Industrial Shoreline Infrastructure Requirements and Land Use Restrictions Associated with Federal Channel Conflict with Planned Mixed-Use Redevelopment & Habitat Enhancements.	Locally-Managed Multi-Purpose Waterway is Consistent with Planned Mixed-Use Redevelopment, Including Infrastructure and Navigation Planning	Locally-Managed Multi-Purpose Waterway is Consistent with Planned Mixed-Use Redevelopment, Including Infrastructure and Navigation Planning	Locally-Managed Multi-Purpose Waterway is Consistent with Planned Mixed-Use Redevelopment, Including Infrastructure and Navigation Planning	Industrial Shoreline Infrastructure Requirements and Land Use Restrictions Associated with Federal Channel Conflict with Planned Mixed-Use Redevelopment & Habitat Enhancements.	Industrial Shoreline Infrastructure Requirements and Land Use Restrictions Associated with Federal Channel Conflict with Planned Mixed-Use Redevelopment & Habitat Enhancements.
ASB Access Channel	Unit 2B	No Use Changes. Area Not Dredged for Marina Access Channel.	No Use Changes. Area Not Dredged for Marina Access Channel.	No Use Changes. Area Not Dredged for Marina Access Channel.	No Use Changes. Area Not Dredged for Marina Access Channel.	Area Dredged Consistent with Plans for Multi-Purpose ASB Marina	Area Dredged Consistent with Plans for Multi-Purpose ASB Marina	Area Dredged Consistent with Plans for Multi-Purpose ASB Marina [9]	Area Dredged Consistent with Plans for Multi-Purpose ASB Marina [9]
Emergent Tideflat	Units 3A	Emergent Shallow-Water Habitat is Preserved, Consistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Dredging of 1960s Industrial Channel Requires Removal of Emergent Shallow-Water Habitat, Inconsistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Dredging of 1960s Industrial Channel Requires Removal of Emergent Shallow-Water Habitat, Inconsistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Multi-Purpose Channel Preserves Emergent Shallow-Water Habitat, Consistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Multi-Purpose Channel Preserves Emergent Shallow-Water Habitat, Consistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Multi-Purpose Channel Preserves Emergent Shallow-Water Habitat, Consistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Dredging of 1960s Industrial Channel Requires Removal of Emergent Shallow-Water Habitat, Inconsistent with Bellingham Bay Comprehensive Strategy Habitat Goals.	Dredging of 1960s Industrial Channel Requires Removal of Emergent Shallow-Water Habitat, Inconsistent with Bellingham Bay Comprehensive Strategy Habitat Goals.
Log Pond	Unit 4	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.	No Change -- Log Pond Cap & Habitat Enhancements Are Preserved. Some Modifications Required to Stabilize Shoreline Edges of Log Pond.
Areas Offshore of ASB									
Shoulder of ASB	Unit 5B	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Creation of Nearshore Habitat in this Area is Consistent with Bellingham Bay Comprehensive Strategy	Conversion of Shallow-Water Area to Deep-Water Area by Dredging is Inconsistent with Bellingham Bay Comprehensive Strategy
Other Unit 5 Areas	Units 5A & 5C	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	No Change. Preservation of Shallow-Water Habitat Areas Along Salmonid Migration Corridors is Consistent with Bellingham Bay Comprehensive Strategy.	Conversion of Shallow-Water Areas Along ASB Berm to Deep-Water Area by Dredging is Inconsistent with Bellingham Bay Comprehensive Strategy Concepts for Salmonid Migration Corridor Enhancements in these Areas
Areas Near Bellingham Shipping Terminal									
Barge Dock Area	Unit 6B, 6C	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Capping Design Not Expected to Impact Planned Navigation Uses.	No Change -- Dredging Has No Impact on Planned Navigation Uses.
Other Unit 6 Areas	Unit 6A	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change -- Dredging Has No Impact on Planned Navigation Uses in this Area.
Starr Rock	Unit 7	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change -- Dredging Limited to Deep-Water Areas
ASB	Unit 8	Capping of ASB Sludges Conflicts with Planned Reuse of ASB for Marina with Integrated Public Access and Habitat Enhancements	Capping of ASB Sludges Conflicts with Planned Reuse of ASB for Marina with Integrated Public Access and Habitat Enhancements	Construction of Nearshore Fill Conflicts with Planned Reuse of ASB for Marina with Integrated Public Access and Habitat Enhancements	Capping of ASB Sludges Conflicts with Planned Reuse of ASB for Marina with Integrated Public Access and Habitat Enhancements	ASB Sludge Removal and Berm Opening is Consistent with Planned Reuse of ASB as Marina with Integrated Public Access and Habitat Enhancements	ASB Sludge Removal and Berm Opening is Consistent with Planned Reuse of ASB as Marina with Integrated Public Access and Habitat Enhancements	ASB Sludge Removal and Berm Opening is Consistent with Planned Reuse of ASB as Marina with Integrated Public Access and Habitat Enhancements	ASB Sludge Removal and Berm Opening is Consistent with Planned Reuse of ASB as Marina with Integrated Public Access and Habitat Enhancements

Notes:

9. Under Alternatives 7 & 8, the marina access channel may have to be relocated to the area offshore of the ASB in order to avoid navigation conflicts between the marina entrance and large-vessel navigation patterns in the Whatcom Waterway.